PROBLEMS AND SOLUTIONS
IN
ELEMENTARY
ELECTRICITY AND MAGNETISM

EMBRACING THE SOUTH KENSINGTON PAPERS
FOR THE YEARS 1885–1899

BY

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ELECTRICAL ENGINEERING FOR ELECTRIC LIGHT ARTISANS AND STUDENTS'

WITH 98 ORIGINAL ILLUSTRATIONS

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PREFACE

THE object of this little book is to supplement the ordinary text-books and class-work, and to afford the student some information as to the method of answering examination papers clearly and concisely.

The recent extensive applications of Electricity in various industries have resulted in the adoption of a more systematic nomenclature than was previously in general use, and we have endeavoured, as far as practicable, to adhere to the more modern terms and expressions. There are, however, many such terms which are beyond the scope of the usual elementary course, and to adopt these, therefore, would tend rather to confuse the student than to assist him.

The student should carefully study the Original Questions which are given on the closing pages of this book: they will be found to cover practically the whole of the South Kensington Syllabus, and the student who can furnish satisfactory answers to those questions may be said to have a very fair knowledge of the rudiments of the science of Electricity and Magnetism. In applying knowledge to the solution of questions, a great deal depends upon the form in which the answer is stated, and every care should be exercised to ensure, not only that every point raised in the problem has been met, but also that no discursive or extraneous matter is introduced.

PROBLEMS & SOLUTIONS

IN

ELECTRICITY & MAGNETISM

1885

MAGNETISM

1. How does the position of a dipping needle change when it is taken from London (i.) towards the north pole, or (ii.) towards the equator?

1. A dipping needle is a magnetised needle suspended so that it can move freely in a vertical plane. Such a needle inclines or points towards whichever of the terrestrial poles happens to be the nearer, and the angle which the needle makes with the horizontal is known as the angle of inclination or the angle of dip.

As the dipping needle is carried towards the north pole of the earth, the north-seeking pole of the needle dips more and more—that is to say, the angle of dip increases—until the vicinity of the north magnetic pole is reached, when the needle will assume a vertical position.

The dip of the needle will be diminished as it is carried towards the equator, and when at the equator it will lie horizontally, the attraction and repulsion of the north and south magnetic poles then balancing each other

2. Two similar rods of very soft iron have each of them a long thread fastened to one end, by which they hang vertically side by side. On bringing near the iron rods, from below, one pole of a strong bar magnet, the rods separate from each other. Explain this.

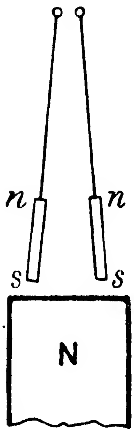

FIG. 1.

2. When the pole of a powerful magnet is brought near the lower ends of the two iron rods, they become magnetised by induction, their adjacent ends being of similar polarity, as shown in fig. 1. Mutual repulsion will then ensue between these similar poles, and the rods will therefore separate.

3. A bar magnet is laid upon a table, and a soft iron bar of about the same length as the magnet is hung horizontally just above it by a flexible string. What will be the effect on the soft iron bar if a second bar magnet be laid on the table and gradually brought near the first, at right angles to it, and with its north-seeking pole pointing to the middle of the first magnet?

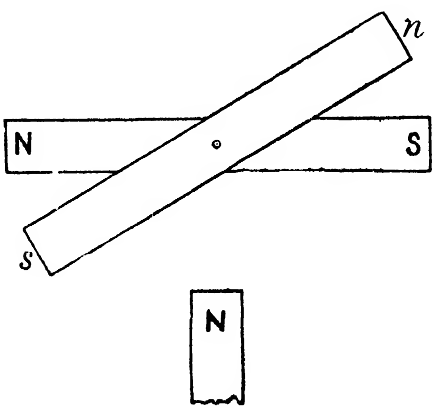

FIG. 2.

3. The soft iron bar *n s* will be magnetised by the fixed magnet, the end of the iron over the north-seeking pole of the magnet becoming a south-seeking pole, and the other end a north-seeking pole. On the approach of the second bar magnet, its north-seeking pole will attract the south-seeking

pole of the iron bar, and deflect it out of its position, the north-seeking pole of the bar being, of course, repelled—so that the bar will tend to take up a position intermediate between the two permanent magnets, as shown in fig. 2.

4. A horseshoe magnet is placed near a compass needle so as to pull the needle a little way round. On laying a piece of soft iron across the poles of the horseshoe magnet, the compass needle moves back towards its natural position. Explain this.

4. When the piece of soft iron is placed across the poles of the horseshoe magnet, the majority of its lines of force are diverted from their previous position and pass through the soft iron, because it affords a much easier path than does the air-space. Consequently fewer lines of force pass out to the needle, the attraction for which is proportionally diminished. The needle therefore returns towards its normal or undeflected position.

FRICTIONAL ELECTRICITY

5. Two pith balls suspended, one by a damp cotton thread, the other by a dry silken thread, are each of them touched by the knob of a charged Leyden jar, which is held in the hand by its outer coating. Will there be any difference between the behaviour of the two balls? If so, what difference; and why?

5. There will be a considerable difference. The silk thread is a good insulator, while the damp cotton thread is a fairly good conductor. Hence, when the pith ball attached to the cotton is touched by the knob of the Leyden jar, the jar will be discharged because the upper end of the thread, if attached to any ordinary support, will be earth-connected, and the outer coating of the jar is already connected to earth through the experimenter's hand and body. The jar will not be instantaneously discharged by a spark, as in the ordinary

way, because the cotton thread offers considerable resistance. The silk-suspended ball will, on the other hand, take only a small portion of the charge pertaining to the inner coating of the jar, and this it will retain because the silk thread is a good insulator. Consequently the ball, being similarly electrified, will then be repelled by the knob of the jar.

6. Two pith balls hang side by side by two damp cotton threads. State and explain what happens when an excited glass rod is brought gradually near the two balls from below.

6. The two pith balls will be acted upon inductively by the positively electrified glass rod, and they will therefore be charged negatively; the positive charge induced simultaneously will be repelled, and will escape to earth by means of the damp cotton threads, which are fairly good conductors of electricity. The induction increases as the rod gets nearer to the balls. The balls, being similarly electrified, are mutually repellent; hence they will diverge, and the divergence will increase as the rod approaches them; but when the rod gets very close to them their mutual repulsion is overcome by the stronger attraction of the glass rod, which is oppositely electrified, and the balls under the influence of this attractive force will then necessarily get nearer together. The probability is that they will ultimately touch the rod on opposite sides.

7. Say exactly what you would do in order to get a succession of sparks from an electrophorus.

7. A spark is obtained from an electrophorus by first rubbing the upper surface of the resinous or ebonite disc with a piece of fur or flannel, which negatively electrifies the surface of the disc. The metal plate is then placed upon the disc, and assumes by induction a positive charge on its lower surface and a negative charge on its upper surface. The plate is then earth-connected for a moment, by the hand or otherwise, which has the effect of allowing the repelled negative charge to escape to earth. The metal cover is next raised by means of its insulating handle, and on the finger approaching the

plate a spark is obtained, due to the escape of the positive charge to earth. A succession of such sparks can easily be obtained by repeating the process so far as the metal plate is concerned; and by taking care that the apparatus is thoroughly dry, a very large number of such sparks can be produced from the single charge developed on the ebonite disc.

8. A brass rod is supported horizontally by a dry glass stem, and a large strongly electrified metal ball is brought near one end of the rod (but not near enough for a spark to pass). The rod is then touched for an instant by the end of an earth-connected wire, and afterwards the ball is removed. Will it make any difference in the final electrical state of the brass rod whether the wire touches it at the end nearest the ball, at the end farthest from the ball, or at the middle? Give reasons for your answer.

8. The result will be the same in every case. When the (say positively) electrified ball A, fig. 3, is brought near one end of the rod B, the rod is electrified by induction, the near end negatively and the remote end positively. When the earth-connected wire touches the rod for a moment the repelled positive charge escapes to earth; and if the electrified ball be then removed, the insulated rod B remains negatively electrified.

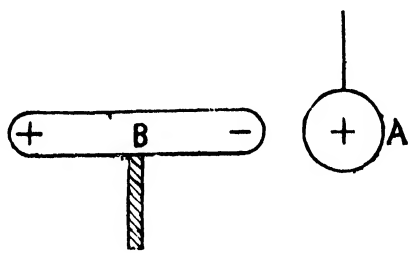

FIG. 3.

The repelled positive charge will escape with equal facility, no matter at what point the earth-connected wire touches the rod; because when the rod is thus earth-connected, it becomes part of a very large conductor into the remote part of which, viz. the earth, the positive charge is repelled. The negative charge cannot under any circumstances escape so long as the positively charged ball remains near the end of the rod, the force

with which it is attracted being in no way altered by the position of the earth-connection.

9. On touching the knob of a charged Leyden jar standing on the floor or on a common table, you get an electric shock; but if either you or the jar stand on a dry cake of resin, you do not get a shock on touching the knob. Explain this.

9. When the inner and outer coatings of a charged Leyden jar are connected by a conductor, the jar is discharged. In the first case, the table, floor, and the experimenter's body form a sufficiently good conducting system to allow the discharge to take place, and the shock experienced is due to the passage of the charge through the body of the experimenter. When, however, such a good insulator as a cake of resin is interposed, either under the jar or under the experimenter, the discharge cannot take place because the inner and outer coatings are not then connected. No shock is therefore experienced.

VOLTAIC ELECTRICITY

10. Give a drawing of a galvanic cell of copper, zinc, and dilute sulphuric acid, showing in what direction the positive current passes through a wire connecting the two metals, and also through the dilute sulphuric acid.

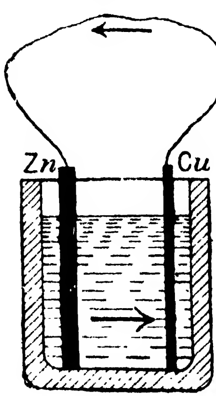

FIG. 4.

10. The diagram (fig. 4) illustrates the construction of a voltaic cell of zinc, Zn, and copper, Cu, immersed in dilute sulphuric acid contained in a jar of glazed earthenware or other non-porous and non-conducting material. The metal plates are shown to be connected by a piece of wire, and the direction of the current inside as well as outside the cell is indicated by arrow-heads.

11. A piece of zinc and a piece of copper are each carefully weighed; they are then connected by a copper wire and dipped side by side into dilute sulphuric acid contained in an earthenware jar. After, say, half an hour, the pieces of zinc and copper are taken out of the acid, washed and dried, and weighed again. Would the weights be the same as at first? If not, how, and why, would they differ?

11. The weight of the copper will be the same, but the zinc will weigh less than before, some of it having been dissolved by the acid solution, and converted into sulphate of zinc. The combination forms, in fact, a simple battery cell, and a current of electricity is obtained at the expense of the zinc plate.

12. A long copper wire covered with silk is wound several times round an iron rod. On connecting the ends of the wire one with each terminal of a Daniell's battery, the iron rod becomes a magnet. How does the direction of magnetisation of the iron (or position of its north-seeking and south-seeking poles) depend upon how the copper wire is wound; and which end of it is connected with the copper end of the battery? Give a drawing.

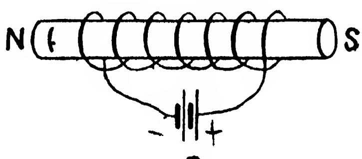

FIG. 5.

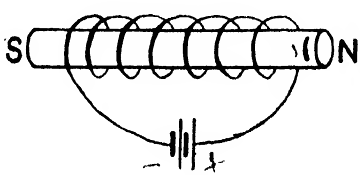

FIG. 6.

12. The direction of magnetisation of the iron depends upon the direction of the current and upon the direction of winding. Fig. 5 shows the effect of joining the battery B to a right-handed helix. The end of such a helix to which the copper end of the battery is connected, and at which, therefore, the current enters,

assumes and imparts to the iron a south-seeking polarity; the reversal of the battery connections would, as it reverses the direction of the current, reverse the magnetisation. Fig. 6 shows the effect of joining the battery B to a left-handed helix. The end of this helix, to which the copper end of the battery is connected, and at which, therefore, the current enters, assumes and imparts to the iron a north-seeking polarity. Were the battery connections reversed in this case, the direction of magnetisation would also be reversed.

13. Wires from two separate voltaic batteries are stretched one above the other from north to south (magnetic), and equal currents pass through both wires. If a magnetic needle free to turn horizontally, but not vertically, is hung halfway between the wires, how will it be affected: (i.) if the currents are both in the same direction; (ii.) if the currents are in opposite directions?

13. (i.) In this case the needle will not be affected, because the current in the upper wire will strive to deflect it in one direction, while that in the lower wire will endeavour to deflect it in the opposite direction. The two currents being equal in strength, and equidistant from the needle, the effort of one of them will be neutralised by that of the other.

(ii.) In this case the needle will be deflected, because the two currents, being opposite in direction, and at the same time on opposite sides of the needle, both tend to deflect it in the same direction.

14. If a plate of copper and a plate of zinc connected by a wire are dipped into dilute sulphuric acid, the connecting wire gets hotter when the plates are brought nearer together, and cooler if they are separated to a greater distance. Why is this?

14. The zinc and copper plates dipped into dilute sulphuric acid constitute a voltaic cell capable of sending a current through the connecting wire. Heat is developed in this wire by the passage of the current; and the current becomes stronger,

and therefore develops a greater amount of heat when the plates are brought closer together, because the resistance offered by the cell is thereby reduced. When the plates are separated to a greater distance, the resistance of the cell is increased, and the strength of the current is proportionally reduced ; the heat developed in the connecting wire is therefore diminished, and the wire becomes cooler.

1886

MAGNETISM

1. If a compass needle is deflected when a steel bar is brought near it, how can you find out whether the deflection is due to magnetism already possessed by the bar or to the bar becoming magnetised by the compass needle at the time of the experiment?

1. By noting the direction of deflection produced by one end of the bar, and then presenting the other end of the bar. If the deflection is in the reverse direction, the effect is due to magnetism already possessed by the bar; but if on both occasions the same end of the needle is attracted, the magnetism of the bar is induced by the compass needle, and is only temporary.

2. Two equal bars of steel, after having been equally magnetised, are kept for some years in a vertical position, one (i.) with its south-seeking pole upwards, the other (ii.) with its north-seeking pole upwards. The bars are kept so far apart that they do not act on each other: which of the two bars would you expect to find had kept its magnetism best, and why?

2. The bar placed with its south-seeking pole upwards would retain its magnetism better than the other, because its lines of force would coincide in direction with those due to the earth, and the latter would be continually endeavouring to keep the bar magnetised. On the other hand, the lines of force pertaining to the second bar would be opposed to those due to the earth, and the latter would therefore be continually striving to demagnetise the bar, and then to magnetise it in the reverse direction.

3. You have given to you two rods, one of soft iron, the other of hard steel; also a compass needle and a bar magnet. Describe experiments with the things provided whereby you could find out which was the iron and which the steel rod.

3. Soft iron differs from steel in having little or no retentivity. If, therefore, one pole of the bar magnet be drawn an equal number of times over the iron and steel bars, the steel will become permanently magnetised, and the iron will not, or at the most very feebly. On presenting either end of the steel rod to the needle, the rod will repel one pole of the needle and attract the other pole. When, however, the iron rod is presented, it will be observed that either end of the rod attracts either end of the needle, and behaves as an unmagnetised mass of iron.

4. A piece of soft iron placed in contact with both poles of a horseshoe magnet at the same time, is held on with more than twice the force with which it would be held if it were in contact with only one pole of the same magnet. Why is this?

4. It is evident that if the piece of soft iron were equally magnetised in both cases—that is to say, if the horseshoe magnet projected the same number of lines of force through it on both occasions—then the force with which it would be held by the magnet would be twice as great when in contact with both poles as it would be when in contact with one pole only. But when the iron is placed across both poles, the number of lines of force passing through it will be far greater; that is to say, it will be more strongly magnetised than when it is in contact with one pole only. Hence the force with which the iron is held when in contact with both poles is more than twice as great as the force with which it is held when in contact with one pole.

FRICTIONAL ELECTRICITY

5. A stick of sealing-wax held in the hand and rubbed with a dry flannel is found to become electrified. A brass rod after being treated in the same way shows no electrification. How do you account for the difference?

5. When the brass rod is rubbed, electricity is developed, just as it is on the sealing-wax; but the metal is a very good conductor, and, as fast as the electricity is developed, it escapes through the body of the experimenter to earth. The sealing-wax, being a good insulator, retains the electricity developed upon it.

6. A stick of sealing-wax, having been rubbed with flannel, is found to be negatively electrified. How, by means of it, would you charge a proof plane with positive electricity?

6. The disc of the proof plane should be brought as close as possible to the electrified rod, and while in that position the disc should be momentarily connected to earth, say, by touching it with the finger. In this way the negative charge induced on the disc would be neutralised or allowed to escape to earth, while the positive induced simultaneously would be retained. The proof plane can then be removed by means of its insulating handle, and the existence of the positive charge demonstrated by means of an electroscope.

7. If an electrified piece of metal is made to touch a gold-leaf electroscope, the leaves separate, and, on taking the metal away, they remain separate. But if the electrified metal is only brought near to the electroscope, and then taken away, the leaves separate when the electrified metal is near, but fall together when it is taken away. Why is there a lasting effect on the gold leaves in one case, and only a temporary effect in the other case?

7. When the electrified piece of metal *touches* the electroscope, it, being a good conductor, imparts a portion of its charge, which remains in the instrument after the piece of metal has been withdrawn. Hence the leaves remain divergent.

When, however, the electrified piece of metal is only placed *near* the electroscope, it imparts nothing, but simply acts by induction, and develops in the instrument equal quantities of positive and negative electricity. One of these is concentrated in the cap near the piece of metal, and the other in the leaves. By the ordinary laws of induction, these charges are kept apart by the proximity of the electrified metal, but when it is removed the charges reunite, and effectually neutralise each other. Hence the leaves in this case fall together.

8. Two insulated metal spheres are brought so as to touch each other. A positively electrified glass rod is brought near to one of the spheres, and while it is there the other sphere is taken away. The glass rod is now taken away. On bringing the spheres near together again a spark passes between them. Give the reason for this.

8. When the positively electrified glass rod approaches the two spheres, it acts upon them inductively, and as they are in contact they behave as a single conductor. Hence, on the part of the sphere A (fig. 7), nearest to the rod, there is a negative charge accumulated, and on the part of the sphere B, remote from the rod, there is a positive charge. When B is removed, it carries its induced charge with it. The rod being now removed, the negative charge is left on A, and when the two spheres are brought near each other, the two opposite charges endeavour to unite and neutralise, and in so doing a spark passes between the spheres.

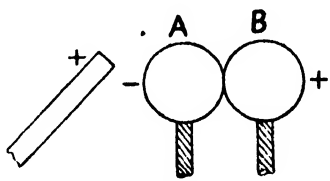

Fig. 7.

9. To prevent a gold-leaf electroscope from being acted on when an electrical machine is at work near it, it is sufficient to cover the electroscope with a thin cotton cloth. How is this?

9. To make this experiment effective, it is essential that the cotton cloth, which is a fairly good conductor, should make

contact with the earth, that is to say, it should touch the base of the instrument, or the table on which it stands. In the absence of the cloth, the prime conductor of the machine would, supposing it to be positively electrified, induce a negative charge in the knob or cap of the electroscope, and repel a positive charge into the leaves, causing them to diverge. But when the electroscope is covered with the cotton cloth, the negative charge is induced on the cloth, the positive escaping to earth, so that the electroscope is effectively screened from the influence of the machine.

VOLTAIC ELECTRICITY

10. How could you boil water by means of the current from a voltaic battery? Give a sketch of the apparatus you would use.

10. Place a spiral of platinum wire near the bottom of a glass vessel containing fairly pure water, the ends of the spiral being connected, by means of two stout copper wires, to the poles of a suitable battery, say, of four Grove cells, as shown in fig. 8. The resistance offered by the water will be sufficiently high, as compared with that offered by the wires immersed in it, to prevent more than a very small proportion of the current leaking across from one copper wire to the other. Practically, therefore, the whole of the current from the battery will pass through the platinum spiral, and if the current be sufficiently strong,

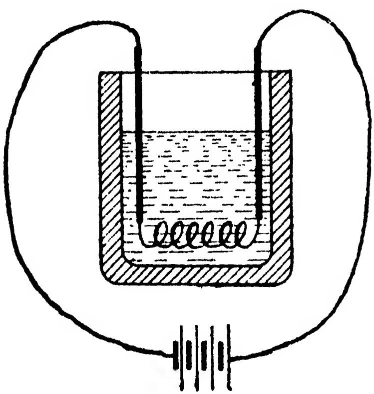

FIG. 8.

it will make the spiral hot, and soon cause the water to boil. If the length of the platinum wire employed be so great that the battery selected cannot send a current through it strong enough to sufficiently raise its temperature, then either the quantity of wire must be reduced or the number of cells increased.

11. One end of a copper wire is fastened to the copper end of a battery, and one end of another copper wire is fastened to the zinc end of the battery. What happens if the other ends of these two wires are put side by side (but not touching) into a solution of sulphate of copper?

11. The current flowing from the battery C, fig. 9, passes through the sulphate of copper solution from the wire A, attached to the copper end of the battery to the wire B, attached to the zinc end of the battery, and in so doing causes chemical decomposition to take place.

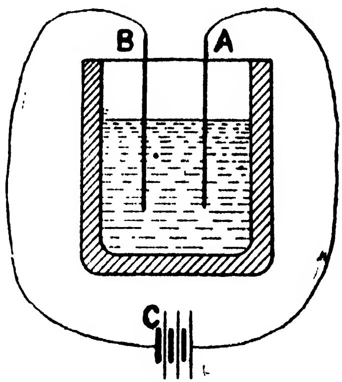

Fig. 9.

The wire A loses some of its copper, which is dissolved in the solution, and an equal amount of copper is precipitated from the solution upon the wire B, which, therefore, gains in weight just as much as A loses, and the quantity of sulphate of copper in the solution remains unaltered.

12. A number of galvanic cells are connected together in a row so as to form a battery. This row is laid on a table so as to lie N. and S. The zinc is to the N. The poles of the battery are connected together by a wire which passes from one pole, up one wall of the room, across the ceiling, and down the opposite wall to the other pole of the battery. How will a magnetic needle be affected which is placed under the table, and just below the battery?

12. The current which passes through the wire passes likewise through the battery from the zinc end to the other that is to say, in this case from north to south. The needle placed immediately under the table will be acted upon inductively by this current, and will therefore be deflected, its north pole pointing eastwards.

13. How is it that a galvanometer with astatic needles is more sensitive than the same instrument would be if furnished only with a single needle?

13. For two reasons: First, because in the case of an astatic pair there are two needles to be acted upon by the current in the coil, although the effect upon the needle outside the coil is not so great as upon the one inside. Secondly, a single needle is held in the zero position by the earth's magnetism with a considerable force, and it is against this force that the current has to act in order to deflect the needle. In the case of a so-called astatic pair, however, the two needles are of almost equal magnetic strength, and are fixed together with their similar poles in opposite directions. Consequently the force holding the pair to zero, that is to say, the force against which the current has to act, is much feebler than in the case of a single needle. It is, in fact, proportional to only the *excess* of the magnetic strength of the stronger needle of the pair over that of the weaker. Hence a galvanometer with astatic needles is more sensitive than the same instrument would be if furnished only with a single needle, or, in other words, a feebler current would suffice to produce a given deflection.

14. If a charged battery is to be kept for some time ready for use, why is it important to take care that the ends of the battery are not connected together outside the battery?

14. If the ends of the battery are directly connected together, the battery is practically short-circuited, and the strongest current which the battery can develop will flow. Hence the battery will be speedily exhausted, and it will possibly be incapable of producing a current when subsequently called upon for useful work.

1887

MAGNETISM

1. A small magnet is placed upon a flat cork which floats in a basin of water, and it is fastened to the cork with a little wax. Describe and explain the behaviour of the magnet (i.) when under the influence of the earth's magnetism alone; (ii.) when an artificial steel magnet is brought near to it.

1. When under the influence of the earth alone, the magnet (*n s*, fig. 10) would be rotated until it pointed towards the magnetic north pole, N. It would experience a force of attraction at its north-seeking pole, and a force of repulsion at its south-seeking pole. These forces would be equal because the two poles of the magnet are practically equidistant from the north pole of the earth, and while, therefore, the earth's force is competent to cause the motion of rotation, the magnet would not be urged bodily to the side of the vessel. For similar reasons the south pole of the earth would assist in directing the magnet, but would be equally incapable of urging it towards the side of the basin.

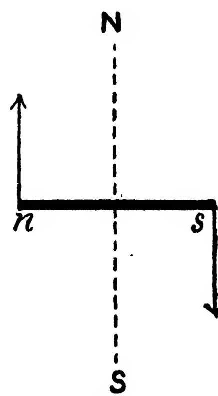

FIG. 10.

When, however, an artificial magnet is brought near, the nearer pole of the floating magnet is appreciably closer to the external magnet than is its remote pole ; hence the floating

magnet turns round, and, with its pole opposite to that of the external magnet, rushes through the water towards it, until it touches the side of the vessel.

2. A compass needle and a straight strip of soft iron of the same length as the compass needle are fastened together so as to be in contact with each other at both ends. Will the force which tends to make the combination point north and south be the same as that which would act on the compass needle alone? Give reasons for your answer.

2. In this case the force tending to make the combination point north and south will be materially less; the compass needle (*n s*, fig. 11) will act inductively upon the strip of iron N S, and magnetise it in such a way that its ends will be of opposite polarity to the ends of the needle to which they are respectively adjacent. The combination is in reality a more or less perfect astatic pair, the earth tending to rotate the compass needle in one direction and the iron strip in the other.

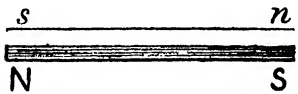

FIG. 11.

3. How would you construct an astatic needle out of a uniformly magnetised strip of watch-spring which you are allowed to bend or break as you please?

3. An astatic needle consists of a pair of magnetised needles (A, B, fig. 12) of equal length, and of equal strength, rigidly fixed together, with their opposite poles adjacent. The strip of watch-spring should therefore be broken into two equal parts, but if when broken the parts are unequal, the longer can be filed or cut down. It would then be necessary to ascertain whether the magnetisations are equal, and if not, to increase the strength of the weaker needle accordingly.

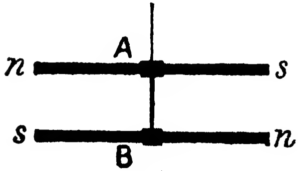

FIG. 12.

As a matter of fact, it is impossible to make the two needles *exactly* equal, but a sufficiently close approximation to equality can easily be obtained. The needles should next be mounted on small brass or other convenient non-magnetic sleeves, and these sleeves connected together by a piece of wire or strip. A simple plan is to use a piece of copper wire for the sleeves and connection. The combination should next be supported by a length of silk fibre mounted on a convenient stand. Thus made the combination will, if truly astatic, remain at rest in any position, instead of pointing north and south. As a rule, one magnet is slightly stronger than the other, and a feeble directive force is therefore exerted by the earth, so that the combination slowly takes up a definite position ; but very little force has to be exerted in order to obtain a deflection.

4. If a compass were carried round the equator, would it point in the same direction at all places? If not, state, as nearly as you can, what changes would be observed in its behaviour during the journey.

4. Starting eastward from the 'line of no declination, which crosses the equator in the northern portion of South America, and where the needle would point due north, it would gradually increase in its deflection to the west until a maximum would be obtained. It would then gradually decrease in this deflection or declination until, when in the middle of the Indian Ocean, it would again point due north. After passing this point there would be a gradually increasing deflection to the east, which would ultimately attain a maximum, when a corresponding reduction in the easterly declination would be maintained until the starting-point was again reached. These variations arise from the fact that the magnetic meridians are coincident with the geographical meridians at only two points, because the magnetic and geographical poles are not coincident. Owing, however, to the irregular magnetisation of the earth, the change in the angle of declination is correspondingly irregular.

FRICTIONAL ELECTRICITY

5. A pith ball is suspended from a metal stand by a fine thread. If you have a strongly electrified glass rod, how can you find out whether the thread is a conductor or a non-conductor of electricity ?

5. When the electrified glass rod approaches the pith ball, induction takes place and attraction ensues. When the ball makes contact with the rod, the small negative charge on its near surface is neutralised by an equivalent of positive on the surface of the glass. If the thread is an insulator, the positive charge on the remote side of the ball remains, and, in consequence, repulsion takes place. But if the thread is a conductor, this positive charge is repelled to earth by way of the brass stand; and the pith ball, instead of being repelled, continues to be attracted, and travelling over the surface of the rod gradually dissipates or neutralises the charge on those portions of the surface with which it comes into contact.

6. If you were given a negatively electrified stick of sealing-wax and two metal balls mounted on insulating supports, how would you, with this apparatus, charge the balls with opposite kinds of electricity? How could you afterwards find out whether you had charged the balls as you intended, and whether their charges were equal or unequal ?

6. This is simply a matter of induction. Let A and B, fig. 13, be the two insulated metal balls placed in contact. The rod of sealing-wax, S, on approaching the balls, develops a positive charge on the near part of B and repels an equal negative charge to the remote part of A. If while S is still close to B the ball A is removed, the two balls will retain their respective charges.

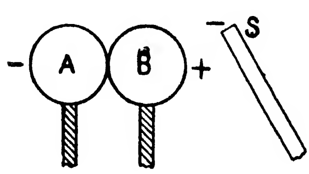

FIG. 13.

An electroscope should now be given a positive charge by induction (by means of the sealing-wax), so that its

leaves remain divergent to a convenient extent. If, now, the ball B be placed near the cap of the electroscope, an increased divergence of the leaves will ensue, proving the ball to be positively electrified. If the ball B be removed, the leaves will resume their original divergent position, but will collapse on the approach of the ball A, thus proving this ball to be negatively electrified. The fact that the charges are equal can be proved by placing the two balls in contact, and then bringing them, in turn, to an uncharged electroscope. Both balls will be found to be unelectrified, thus proving that the positive charge on B has neutralised the equal negative charge on A.

7. An insulated conductor, A, is brought near to the cap of a gold-leaf electroscope which has been charged positively. State and explain what will happen (1) if A is unelectrified; (2) if it is charged negatively.

7. This, again, is a matter of induction. The electroscope being positively electrified, its charge will act inductively on the unelectrified conductor A, developing a negative charge on the near portion of it, with the result that the leaves will collapse more or less completely, due to the mutual attraction between the negative on A and the positive in the electroscope; but the divergence will be restored on the withdrawal of A from the electroscope.

When A is charged negatively, it acts inductively on the electroscope, withdrawing the positive charge from the leaves into the cap, and if the charge on A is sufficiently great, it will, at a certain distance, cause a total collapse of the leaves. On approaching yet nearer, further induction will take place, and the positive charge in the cap will be increased, while the negative equivalent to this increase will be repelled into the leaves, causing them to again diverge.

8. Describe any experiment by which you could prove that when electrification of one kind is produced, the opposite kind is also produced in equal quantity.

8. If a piece of dry flannel be insulated from the hand by means of a sheet of indiarubber, or an indiarubber glove, and

then rubbed over a rod of ebonite, equal and opposite charges can be developed on the flannel and ebonite respectively. If they be brought, in turn, to an electroscope, a divergence of the leaves will be obtained, proving both to be electrified ; but if both be placed together on the cap, there will be no divergence, proving that the two charges are opposite and equal, since their effects neutralise each other. The experiment illustrated in fig. 13 also demonstrates that the two electric states are developed together and in equal quantity.

9. An orange into which a sewing needle has been stuck, point outwards, is suspended by a dry silk thread. A charged body is brought near to it (i.) opposite the point of the needle; (ii.) opposite the side remote from the needle. State and explain the electrical effect in each case.

9. Let A, fig. 14, be the orange, and N the needle. Let B be the charged body, and let its charge be, say, positive. It will, in the first case, act inductively on the needle, developing negative at the point and repelling the positive to the remote side of the orange. The negative charge will, however, owing to the sharp point on the needle, be rapidly discharged against B, but the positive charge on the remote side of A will remain until B is removed. In that case the charge would distribute itself over the orange and needle, becoming very dense at the point of the needle, from which it would be rapidly dissipated. This positive charge would therefore soon disappear.

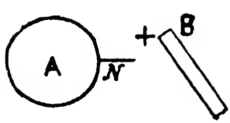

FIG. 14.

In the second case a negative charge would be developed on the side of the orange remote from the needle and adjacent to B, while the equivalent positive would be repelled into the needle. This latter charge would, however, owing to the effect of pointed conductors, be speedily dissipated, leaving only the negative charge on the orange. This would be retained as long as B remained near, but the withdrawal of B would be promptly followed by the dissipation of this charge also from the point of the needle.

The discharge from a pointed conductor is mainly a convectional one, that is to say, portions of the charge are communicated to adjacent air-particles; these are speedily repelled, and, others taking their places, take up other portions of the charge. These are in like manner repelled and make room for others, and so on until no charge at all is left.

VOLTAIC ELECTRICITY

10. Describe and explain any workable experiment to prove that the terminals of a galvanic battery differ electrically in the same way as the conductors and rubber of an electrical machine at work, but to a less extent.

10. This can be demonstrated by joining the poles of a battery consisting of a number of cells to a pair of insulated metallic plates placed with their faces parallel and vertical, and suspending between them a single gold leaf, insulated and charged. Such an arrangement is illustrated in fig. 15, where the leaf C is charged positively, preferably by means of an electrophorus. The plate B is connected to the copper and the plate A to the zinc end of the battery. If these plates are brought sufficiently near to the leaf, it will be repelled from B and attracted by A, thus showing B to be positively, and A negatively, electrified. To confirm these results the leaf may be electrified negatively, when it will be repelled by A and attracted by B.

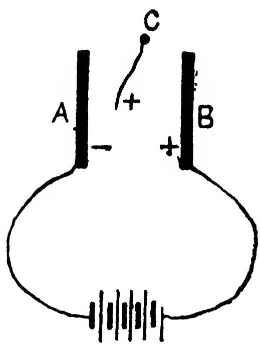

FIG. 15.

Precisely similar results may be obtained by joining the insulated rubber of an electrical machine to the plate A, and the prime conductor to the plate B. In this case, however, the degree of electrification is much higher than that produced by

the battery, and it therefore becomes necessary to remove the plates to a greater distance to avoid injury to the leaf. It can thus be proved that the rubber of the machine corresponds to the zinc end of the battery, and the prime conductor to the copper end of the battery.

11. The platinum and copper plates of a Grove's and a Daniell's cell are connected by a wire. Would there be a current if the zinc plates were also connected; and, if so, in which direction would it flow?

What reason have you for your answer?

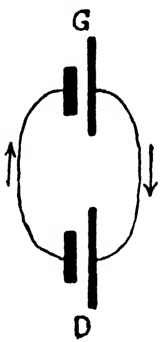

FIG. 16.

11. The two cells would be joined up as shown in fig. 16 in such a manner that the Daniell cell D would be striving to urge a current in one direction, while the Grove cell G would be striving to urge a current in the opposite direction round the circuit. If the electromotive force of one cell were equal to that of the other, no current would flow; but where they are unequal, the resultant electromotive force is that due to the difference between the two electromotive forces. In this case the electromotive force of the Grove cell is almost twice as great as that of the Daniell cell, and consequently the former would send a current round the circuit in the direction shown by the arrows.

12. The current from a voltaic battery is passed at the same time through a thin wire and through dilute sulphuric acid, connected in series. What will happen to the wire and to the dilute acid; and what change (if any) will be produced in each case by reversing the battery connections, so as to alter the direction of the current through the wire and liquid?

12. When a current passes through a solid conductor, heat is developed; and if the conductor be thin, so as to offer considerable resistance, and the electromotive force be sufficiently

high, it may be made red- or white-hot. The same current passing through acidulated water would chemically decompose the water into its constituent gases, oxygen being liberated at the metal electrode by which the current enters the liquid, and hydrogen being liberated at the negative electrode, or that electrode by which the current leaves the liquid. On reversing the battery connections, no difference would be perceived in the effect upon the wire, because, after the first moment or so, the current becomes of exactly the same strength as before the reversal; but in the case of the water, the gases would be liberated at the opposite electrodes; that is to say, the electrode at which oxygen previously appeared will now liberate hydrogen; and similarly oxygen will now be set free at the electrode at which hydrogen was previously liberated. The two gases may be collected by placing tubes, closed at their upper extremities, over the electrodes, and the hydrogen can then be distinguished from the oxygen by the fact that it is generated twice as fast.

13. Two compass needles are arranged near each other so that both point along the same straight line. A wire connecting the platinum and zinc ends of a battery is stretched vertically halfway between the needles. How will the current in the wire affect the needles, and how will the result depend upon whether the platinum terminal is connected with the upper or lower end of the wire respectively?

13. Let w, fig. 17, be a sectional view of the vertical wire, and *a b* the line along which the needles point in the absence of

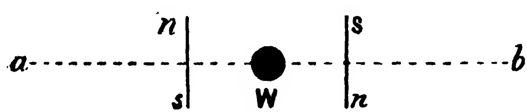

FIG. 17.

the current. Then as soon as the current commences to flow the needles will tend to turn round and take up positions at

right angles with the wire. If the platinum terminal is connected to the upper end of the wire, so that the current flows downwards, the needles will take up the positions shown in the figure. If the battery connections are reversed, so also will be the directions in which the needles point.

14. If you were given any galvanic cell you chose, wire with an insulating covering, and a bar of soft iron, one end of which was marked, state exactly what arrangements you would make in order to magnetise the iron so that the marked end might be a north-seeking pole. Give a diagram.

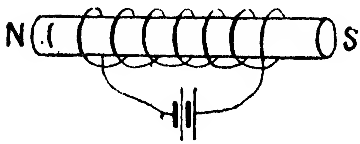

FIG. 18.

14. The wire should be wound as a helix over the iron bar. In fig. 18 the wire is wound as a right-handed helix, and the current being made to enter at the end S, a south-seeking pole would be developed at that end, and a north-seeking pole at the marked end N.

1888

MAGNETISM

1. An astatic combination of two magnets is injured so that the magnets are at right angles instead of parallel to each other. If it be suspended as usual, what position will it assume with regard to the magnetic meridian? Illustrate your answer with a diagram showing the forces which act upon the magnets.

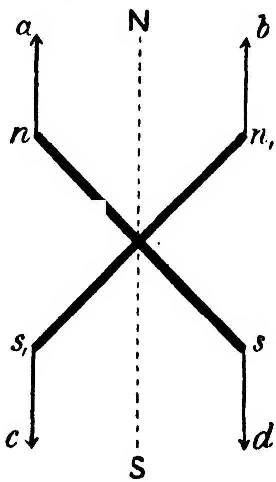

FIG. 19.

1. The combination will set itself so that the magnetic meridian N S passes midway between the similar poles, as shown in the diagram, fig. 19. The forces acting on the north-seeking poles will be in the directions *n a* and $n_{,}\,b$, and those acting on the south-seeking poles will be in the directions $s_{,}\,c$ and *s d*.

2. A strong bar magnet is placed on a table with its axis lying in the magnetic meridian, and with its north-seeking pole towards the north. State in what direction a compass needle points (i.) when placed immediately over the centre of the bar magnet; (ii.) when gradually raised vertically upwards.

2. When a compass needle is suspended immediately over a strong bar magnet lying in the meridian with its north-seeking pole towards the north, the magnet will act more powerfully than the earth, and consequently the needle will set with its south-seeking pole pointing northwards, and its north-seeking pole southwards. As the needle is raised, the effect of the magnet becomes gradually less, but the force due to the earth remains practically unaltered, and presently a point will be reached where the two forces, due to the magnet and the earth respectively, balance each other. In this particular position there is no decided directive force acting upon the needle ; but if it be raised yet further above the magnet, the earth's force will predominate, and the needle will set itself with its north-seeking pole pointing northwards.

3. Two bars of soft iron are so placed to the east and west of the north pole of a compass needle that the needle still points north and south. If the iron to the east of the needle be replaced by a bar of hard steel of exactly the same size and shape as itself, will the direction in which the magnet points be altered? If so, in which direction will it move ; and why?

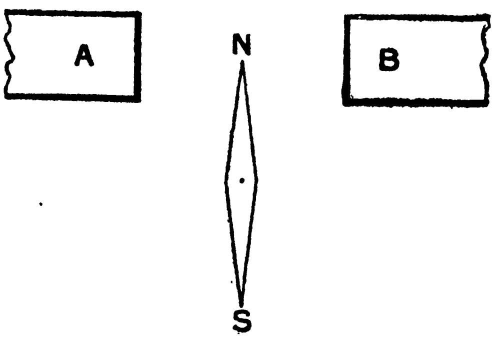

FIG. 20.

3. Let N S (fig. 20) be the needle and A and B the bars of iron; then by induction the nearer ends of the two bars will both

assume south-seeking polarity; but they can easily be placed so as to just neutralise each other's effects upon the needle. Hard steel is less easily magnetised than soft iron; hence the south-seeking polarity induced in the near end of the steel bar substituted for the iron bar B will be feebler than that in the iron bar A. The latter will then act more powerfully than the steel bar upon the north-seeking pole of the needle, which will therefore be deflected towards the west.

4. What is meant by saying that the magnetic dip at London is 67° 30′?

State in general terms at what places on the earth's surface the magnetic dip is least.

4. Magnetic dip is the inclination or angle which a needle free to move in a vertical plane makes with the horizontal line drawn through its centre or point of suspension. It is due to the fact that such a needle tends to point directly towards the nearer of the earth's magnetic poles. In London the north-seeking pole of a dipping needle points downwards towards the north magnetic pole of the earth, and the angle which a line joining the poles of the needle makes with the horizontal is there found to be 67° 30′, which is said to be the magnetic dip at London.

When the earth's poles are equidistant, the needle lies horizontally, and there is then no dip. This occurs along a line round the earth, about midway between the magnetic poles, and called the magnetic equator. It is not quite coincident with the geographical equator, but does not diverge materially from it.

FRICTIONAL ELECTRICITY

5. How would you prove to a class that there are two kinds of electricity?

5. Place an unelectrified smooth glass rod in a wire or other stirrup suspended by a thread (the conductivity of which

is immaterial). Rub another smooth glass rod with silk, likewise an ebonite rod with flannel, and bring these electrified rods in turn near the suspended rod; attraction follows in both cases. This proves both rubbed rods to be electrified. Now electrify the suspended rod by removing it from the stirrup and rubbing it with silk. Let this rod be again suspended, and bring the other previously electrified rods in turn near it. It will be observed that the electrified ebonite attracts the electrified glass, but that the suspended rod is repelled by the other electrified rod of glass. As opposite results are the outcome of opposite causes, it is clear that the electrification of the ebonite rod differs from that of the glass rod which was held in the hand, and as the two similar glass rods were rubbed with the same piece of silk, we may fairly assume them to be similarly electrified, while the flannel-rubbed ebonite is differently or oppositely electrified. Hence the law is deduced that bodies similarly electrified are mutually repellent, while bodies dissimilarly electrified are mutually attracted. These deductions can be confirmed by providing a second rod of ebonite, and after rubbing it with flannel suspending it in the stirrup. Electrified glass will be found to attract the ebonite, while the other electrified ebonite rod will repel it.

6. A rod of sealing-wax is rubbed with dry flannel. An uncharged pith ball suspended by a silk thread is attracted when the sealing-wax is brought near to it, but is unaffected by the flannel. Would you conclude from this experiment that when sealing-wax and flannel are rubbed together, the sealing-wax only is electrified? Give reasons for your answer.

6. We should not be warranted in assuming that the sealing-wax alone is electrified. In fact, if we insulate the flannel from the hand, say, by a sheet of indiarubber, and then rub the sealing-wax with the flannel, we shall find the flannel to be electrified. If the flannel and the sealing-wax be placed together on the cap of an electroscope, there will be no divergence of the leaves, but either the flannel or the sealing-wax alone will cause a divergence. Hence both

bodies are electrified, and their electrifications are equal and opposite. The charge generated on the uninsulated flannel simply escaped through the hand and body of the experimenter.

7. When the handle of an ordinary frictional machine is turned, sparks can be drawn from the prime conductor. Explain carefully how the prime conductor becomes charged with electricity.

7. When the plate of the machine is rotated, the friction between it and the silk rubber develops a positive charge upon the part of the glass which is rubbed. Glass being an insulator, this charge remains on that part of the surface on which it is generated. Consequently, as the plate rotates, it carries the charge with it. As this charge approaches the prime conductor induction takes place, a negative charge is attracted to the teeth of the comb, and an equal positive charge is repelled to the remote part of the conductor. As the glass gets opposite the comb, the negative charge accumulated there passes by convection from the points of the teeth on to the plate and neutralises the positive charge. Hence the conductor is left with a positive charge, and the neutralised or unelectrified glass is carried round to the rubber when electrification and the other subsequent operations are repeated.

8. A sharp point attached to a conductor A is held near an insulated charged conductor B. What will be the effect on B if A is (i.) insulated; (ii.) uninsulated?

8. Assuming the charge on B to be positive, then (i.) when the point attached to the insulated conductor A approaches B, induction takes place. The negative charge passes freely by convection from the point on A and partially neutralises B, thus leaving both conductors with a positive charge. (ii.) When the conductor A is uninsulated, it forms practically a part of a very large conductor, viz. the earth. As before, the negative streams off the point attached to A, but is continued until the charge on B is quite neutralised. The positive developed on A passes

away into the earth, so that both A and B are finally left in an unelectrified condition.

9. The inner coating of a Leyden jar is connected by a wire with the prime conductor of an electrical machine, and also with a gold-leaf electroscope. If the jar rests upon a sheet of glass, a quarter of a turn of the machine produces a large divergence of the leaves of the electroscope. If the glass be removed, ten turns of the handle are required to produce the same deflection. Explain this.

9. Let P, fig. 21, be the prime conductor, L the Leyden jar, E the electroscope, and G the glass plate. When a number of conductors are electrically connected together, any charge imparted to the system divides itself among the conductors, so as to bring all of them at once to the same potential. Now some conductors require more electricity than others in order to

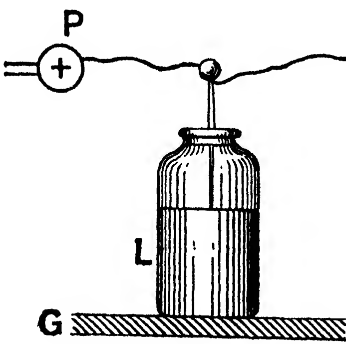

FIG. 21.

effect a given increase in potential, and those which thus require more are said to have a higher capacity than those which require a smaller amount. In this case the size and construction of the Leyden jar give to it a greater capacity than pertains to the electroscope E. But the difference in capacity is increased enormously when the outer coating is uninsulated, that is to say, when the glass plate G is removed.

Now a given divergence of the gold leaves can under the

same conditions be reproduced by imparting to them the same quantity of electricity. Hence, when L is placed on G, so that the capacity of L is comparatively low, a small charge communicated by P raises both L and E to the same potential, the proportion of the charge taken by E being sufficient to cause a considerable divergence of the leaves. But when G is removed, the capacity of L rises considerably, and as a consequence much more electricity has to be communicated by P before the potential of the system is raised to its previous value, that is to say, before a sufficient charge passes into E to reproduce the original divergence. It should be noticed that as nothing is done to E during the experiment, its capacity remains unaltered, and the quantity required by it to reproduce the divergence is the same.

VOLTAIC ELECTRICITY

10. An insulated positively electrified gold leaf hangs halfway between two vertical insulated and unelectrified copper plates A and B, to each of which a copper wire is attached. If plates of zinc and copper, which are partly immersed in dilute acid, are touched by the wires attached to A and B respectively, and if afterwards the wires are both dipped into the acid, describe the movements of the gold leaf in each case.

10. When the plates A and B (fig. 22) are connected by the wires W W with the zinc plate Z and the copper plate C respectively, partly immersed in dilute sulphuric acid, A assumes a negative and B a positive potential, the difference of potential between the two being the same as that at the ends of the zinc and copper plates. Consequently the positively electrified gold leaf G will be repelled from B and attracted towards A. Should the wires W W be then dipped into the solution, the two plates A and B will be discharged or restored to a common potential, because they are then connected together through the solution, and no difference of potential is produced when

two similar metals are placed in the same solution; and the gold leaf being midway between the plates is not attracted by either. If, however, the removal of the wires from the zinc and copper plates be effected without bringing them into contact either directly or through the experimenter's body, the plates will retain their charges until the wires touch the solution, and the leaf will retain its position nearer to A than to B. When, however, the plates are connected through the solution, the electrified leaf G will still keep them electrified by induction, and being nearer to A than to B, it will induce upon it a considerable negative charge, and remain attracted thereto.

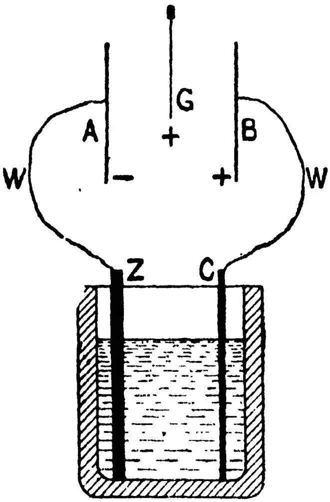

FIG. 22.

11. What are the materials used in the construction of a Daniell's cell, and what chemical changes occur in the cell when in action?

11. A Daniell cell (fig. 23) consists of an outer non-porous vessel of convenient shape, circular or rectangular, divided into two compartments by means of an unglazed porous earthenware plate or pot. Into one of the compartments is placed a zinc plate, rod, or cylinder, and into the other a copper plate or cylinder. It is usual to employ zinc of considerably greater thickness than the copper. Theoretically the zinc cannot be too thick, nor the copper too thin. The compartment containing the zinc is nearly filled with clean water, or with a solution of sulphate of zinc, or with a weak solution of sulphuric acid With the copper plate is placed a saturated solution of sulphate of copper, a quantity of sulphate of copper crystals being also

placed in the cell. The crystals are freely soluble, so that the saturated solution is readily maintained.

Supposing that we first consider the action which results when an acid solution is placed in the zinc compartment. On the outer ends of the metal plates being joined together by a wire, the current begins to flow, and particles of the zinc plate are dissolved by the acid, from which the hydrogen is set free. This hydrogen is ultimately liberated in contact with the sulphate of copper solution, and displacing the copper therefrom forms fresh molecules of sulphuric acid. The displaced copper is eventually deposited in a very pure crystalline state upon the surface of the copper plate, which consequently gets thicker as the generation of the current is maintained. The changes which take place are depicted in the following equation :—

$$Zn + SO_4H_2 + SO_4Cu = ZnSO_4 + H_2SO_4 + Cu.$$

From this it will be seen that for every atom of zinc dissolved by the passage of the current an atom of copper is deposited upon the copper plate. The total quantity of sulphuric acid remains the same, although it does not necessarily follow that the whole of it is retained in the zinc division. A molecule of sulphate of zinc is formed for every molecule of sulphate of copper which is decomposed. Ultimately, therefore, the zinc plate and sulphate of copper must be renewed, while the sulphate of zinc and sulphuric acid solution must be diluted.

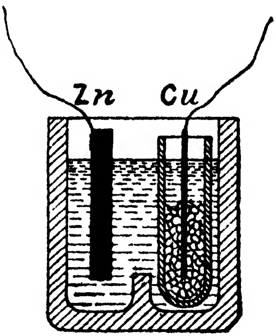

FIG. 23.

In practice, where Daniell cells are used in considerable numbers, water alone is placed with the zinc, and by ordinary diffusion some of the sulphate of copper solution passes through the porous partition into the zinc division. Sulphate of copper is very unstable ; that is to say, its constituents have very little affinity for one another ; and once in the zinc division, the sulphate of copper is speedily con-

verted into sulphate of zinc. The zinc is of course derived from the zinc plate, and the displaced copper is thrown down on the surface of the zinc or on the bottom of the cell, where it accumulates as 'battery mud.' With an average porous partition sufficient sulphate of zinc will have been formed in thirty-six or forty-eight hours for the cell to start working at its normal rate. When a cell is required to be of standard electromotive force the zinc division is provided with a semi-saturated solution of sulphate of zinc, so that it can be employed at once. In the absence of sulphuric acid the chemical changes which take place are represented by the equation

$$Zn + SO_4Zn + SO_4Cu = ZnSO_4 + ZnSO_4 + Cu,$$

so that no hydrogen is freed at all. Should the sulphate of copper solution be allowed to get weak, water will be decomposed and hydrogen deposited on the copper plate. Polarisation will then ensue.

12. Plates of platinum and copper are dipped into a solution of copper sulphate. What effects are produced upon them if a current is passed through the liquid from the copper to the platinum?

12. The passage of the current will cause a gradual dissolution of the copper plate and a corresponding and exactly equal deposition of copper from the solution upon the platinum plate. This arises from the fact that the solution contains the same metal as that of the plate by which the current enters the solution. The chemical changes are represented by the equation

$$Cu + SO_4Cu = CuSO_4 + Cu.$$

13. A current flows through a copper wire which is thicker at one end than the other. If there is any difference either (i.) in the strength of the current at, or (ii.) in the temperature of, the two ends of the wire, state how they differ from each other, and why.

13. The strength of a current is the same in all parts of a simple or undivided circuit, so that the current strength will be

the same in both ends of the wire under consideration. The work done upon the various parts of a circuit, however, varies directly as their resistances, and the result of the work done by a current in a conductor is to develop heat in it. Hence the heat developed in the two ends of the wire will be directly proportional to their resistances; but the resistance of a conductor varies inversely as the square of its diameter; therefore more heat will be developed in the thin than in the thick end. Again, in the thin end there is less metal to make hot than in the thick end; and for this reason also the thin end will get hotter than the thick end.

14. An insulated copper wire is wound round a glass tube AB from end to end, and a current is sent through it, which to an observer looking at the end A appears to go round in the same direction as the hands of a watch. A rod of soft iron is held (i.) inside the tube; (ii.) outside but parallel to the tube. What will be the magnetic pole at that end of the bar which is nearest to the observer in each case?

14. The end of the helix at which the current enters, as in the diagram, fig. 24, becomes the south-seeking pole, and the other end the north-seeking pole of the helix. When a piece of iron

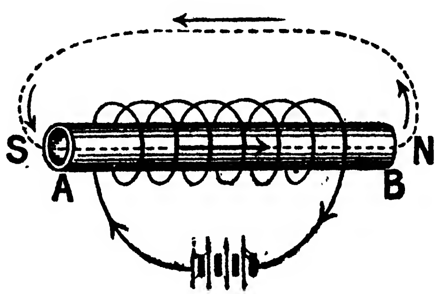

FIG. 24.

is placed in a magnetic field, the lines of force pass freely through it, and rearranging its particles cause it to be magnetised in the direction in which the lines of force pass through it. The

direction of the lines, due to the current in the helix, is illustrated by the dotted lines and arrow-heads. Therefore a piece of iron placed inside the helix is polarised in the same direction as the helix, that is, with a north-seeking pole at N, and a south-seeking pole at S. When the iron is placed outside, the polarity is reversed, that is to say, the end near N becomes a south-seeking pole, and the end near S becomes a north-seeking pole.

1889

MAGNETISM

1. A bar of soft iron AB is placed horizontally east and west, the east end A being about four inches to the west of the north-seeking pole of a compass needle. The end A being fixed, B is raised until the bar is vertical. How is the needle affected by the bar when in its original and final positions?

1. Let A B, fig. 25, be the bar of soft iron placed east and west, and N S the compass needle. In the position shown,

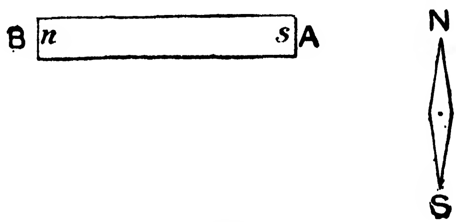

FIG. 25.

with A B horizontal, the north-seeking pole of the needle induces south-seeking polarity in the near end of the iron, and the needle is therefore attracted and deflected towards it. As the end B is raised, the earth's lines of force pass through it, and when in the vertical position, the length of the bar approximately coincides with the lines of force of the earth's field; hence A becomes a north-seeking pole. The north-seeking pole of the needle is then repelled and deflected towards the east. If the needle were placed close to the end of the bar, the inductive

effect of the needle would be greater than that of the earth, and the needle would still be attracted, although less powerfully than when the bar was horizontal.

2. The beam of a balance is made of soft iron. When it is placed at right angles to the magnetic meridian two equal weights placed in the opposite pans just balance. Will the weights still appear to be equal when the balance is turned so that the beam swings in the magnetic meridian? Give reasons for your answer.

2. When the beam is placed at right angles to the magnetic meridian it remains unmoved by the earth's magnetism, the

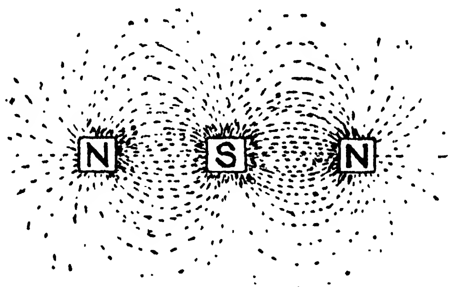

FIG. 26.

lines of force passing through it from one side to the other, and therefore not differently affecting its ends. When, however, the balance is placed so that the beam swings in the magnetic meridian, the lines of force due to the earth pass lengthways through it, and magnetise it in such a way that its north-pointing end is a north-seeking pole. The beam will therefore strive to take up a position in the line of dip, and the pans will therefore no longer balance, although the weights are equal.

3. An iron ball is held over a pole of a horseshoe magnet. Will the attraction exerted on the ball be altered if the poles of the magnet are connected by a soft iron keeper; and if so, in what way, and why?

3. When the soft iron keeper is placed over the poles of the

magnet a large proportion of the lines of force will pass through it instead of through the iron ball; consequently the attraction for the ball will be considerably lessened.

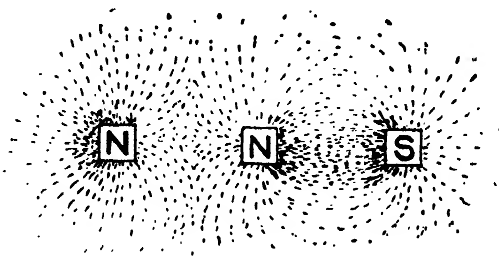

FIG. 27.

4. Three precisely similar magnets are placed vertically, with their lower ends on a horizontal table. Iron filings are scattered over a plate of glass which rests on their upper ends, two of which are north poles and the third a south pole. Give a diagram showing the forms of the lines of force mapped out by the filings.

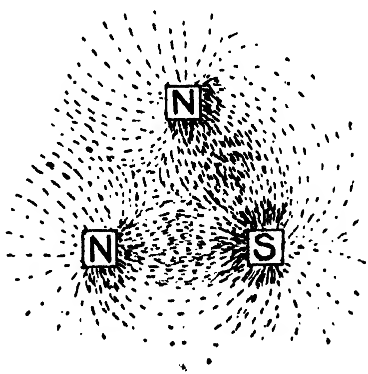

FIG. 28.

4. Either of the three diagrams here given (figs. 26–28) will meet the requirements of this question. The arrangement of the filings between two similar poles is very different from that obtained between dissimilar poles. The universal tendency is for the filings to arrange themselves along lines connecting opposite poles. They never arrange themselves along lines which would connect similar poles, but apparently glance off from each other, as shown in the diagrams, in such a

manner as to appear to indicate the force of repulsion which we know to exist.

FRICTIONAL ELECTRICITY

5. An electrified metal ball is introduced into a dry glass tube closed at one end, and then, the tube being held in the hand, is brought near to the cap of an electroscope. What will the effect on the electroscope be if the exterior of the tube (i.) is, (ii.) is not, covered with tinfoil?

5. When the tube is uncovered the charge on the ball will act through the glass, and induce an opposite charge on the cap of the electroscope, repelling the similar charge to the leaves, which will in consequence diverge.

When the tube is covered with tinfoil the electrified ball will be practically enclosed in a hollow conductor which is earth-connected through the hand of the experimenter. Hence the charge on the ball will develop an equal and opposite charge on the inner face of the tinfoil, while the corresponding similar charge will escape to earth. There will therefore be no effect upon the electroscope.

6. The extremity B of a wire A B is attached to the plate of a gold-leaf electroscope. By means of an insulating handle the other end A is placed in contact first with the blunt and then with the more pointed end of a pear-shaped insulated and electrified conductor.

Describe and explain the movements of the leaves of the electroscope.

6. The pear-shaped body P, fig. 29, being a conductor will be raised to a uniform potential when a charge of electricity is communicated to it; consequently when the end A of the wire A B touches the blunt end of P, the divergence of the leaves of the electroscope E will be the same as that obtained when the wire touches the more pointed end of P. For if P is at all points at the same potential, a conductor such as the wire and

electroscope connected with it at either end will in each case be raised to the same potential; and as the divergence of the leaves is dependent upon the difference of potential between

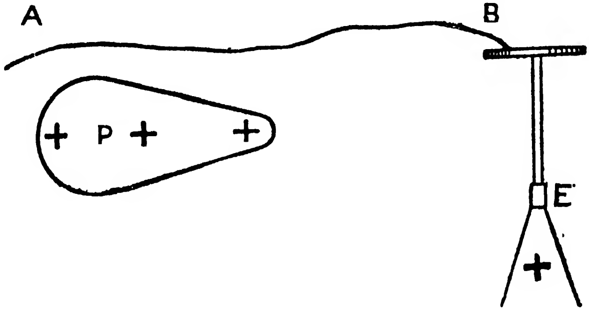

FIG. 29.

the leaves and the glass (which is throughout at a common potential, viz. that of the earth with which it is connected), it follows that the divergence must be the same in each case.

7. You charge a Leyden jar by holding its outer coating in the hand, and bringing the knob to the prime conductor of an electrical machine. If you wished to charge the jar to as high a potential as possible, would you hold the knob in contact with the prime conductor, or keep them a small distance apart? Give reasons for your answer.

7. The jar would be charged to the highest possible potential when placed in contact with the prime conductor, for then it could be charged to the same potential as the conductor itself, and it would be impossible by any arrangement to charge it to a higher potential than the conductor.

When, however, the knob of the Leyden jar is separated by a small distance from the knob of the prime conductor, the jar can only be charged by sparks passing from the conductor across the air-space. Now, in order that these sparks may pass, it is necessary for a definite *difference* of potential to be established between the prime conductor and the knob of the jar. It follows, therefore, that in this case the inner coating of the Leyden jar can never be raised to a potential equal to that of the prime conductor.

8. A muslin bag containing sulphur and red lead finely powdered is suspended by a silk ribbon so that it hangs within a metal vessel which stands on the cap of an electroscope. When the bag is jerked the powders are shaken out through the muslin into the vessel, and become electrified by friction. State and explain what effect (if any) is produced upon the electroscope.

8. As the powders are shaken through the bag they are subjected to friction, and are accordingly electrified, one with a positive charge, and the other with a negative charge. The two charges are of course equal, and consequently when the particles fall to the bottom of the metallic vessel, the effect of the one set is neutralised by the effect of the other, and there is therefore no divergence of the leaves of the electroscope.

9. Sparks pass between the prime conductor of an electrical machine and a metal knob, connected with the earth, held near to it. Describe the changes (if any) in the phenomena observed as the knob is gradually moved away from the prime conductor.

9. When the metal knob is near the prime conductor, it requires a comparatively small potential difference to overcome or break down the resistance of the intervening air. Consequently the sparks succeed one another with great rapidity, and they appear as an almost continuous, straight, luminous line, accompanied by a sharp sound. As the distance increases the sparks become less frequent, for it takes a longer time to generate sufficient electricity to raise the prime conductor to the potential necessary to cause a spark to pass. The sparks become less straight, and after a time appear more or less zigzag. The sound accompanying the lengthened spark grows decidedly louder, and the brilliance of the spark likewise increases until the distance gets too great for a spark to pass, when there is again a continual discharge, which now takes the form of a pale bluish brush, known as the brush discharge, and is accompanied by a remarkable hissing sound.

VOLTAIC ELECTRICITY

10. A number of cells formed of plates of zinc and platinum immersed in dilute sulphuric acid are to be connected in a circuit, so that the platinum of each cell is in contact with the zinc of the next. What effect (if any) would be produced on the current if, by mistake, one cell were made up with two platinums instead of with one platinum and one zinc plate?

10. If one of the cells were made up with two platinum plates instead of one zinc and one platinum, the platinum which should be replaced by the zinc would not be attacked and oxidised by the solution, and the cell would not therefore provide its share of electromotive force. The strength of the current would on this account be proportionally weakened. Further, the passage of the current between the platinum plates would decompose the solution, oxygen would be released on the surface of the plate by which the current enters, and hydrogen on the surface of the other plate, and these two gases, hydrogen being electropositive to oxygen, would set up a counter electromotive force, which would in effect reduce the available electromotive force of the battery, and in that way the strength of the current would be further diminished.

11. A wire lies east and west (magnetic) immediately over a compass needle. How is the direction in which the needle points affected when a strong current flows through the wire (i.) from west to east; (ii.) from east to west?

11. When the current flows through the wire from west to east, it sets up a magnetic field in which the lines are coincident with the lines of force due to the needle in the position in which it is held by the earth. Therefore, there is no effect upon the needle, except to confirm it in its position and render it more difficult for any other disturbing influence to move the needle.

When the current flows from east to west the field set up thereby in the region of the needle is opposite in direction to

the earth's field and to the lines due to the needle. The needle will therefore tend to turn round so as to point in exactly the opposite direction, that is to say, with its north-seeking pole towards the south. The invariable effort of different sets of lines of force projected across the same space or region is to coincide in direction. If the current is sufficiently strong it will succeed in completely turning the needle round.

12. Why is an astatic galvanometer better adapted for the measurement of weak currents than a galvanometer with a single needle?

12. For the reasons given in answering question No. 13, 1886, an astatic galvanometer is more sensitive than one with a single horizontal needle. It follows therefore that the astatic galvanometer would indicate the passage of a weak current, or a slight variation in a current already flowing, which would be imperceptible with a single needle instrument.

13. Two Grove's cells, alike in all respects except that in one the plates are twice as far apart as in the other, are arranged in series, and the poles of the battery so constituted are united by a copper wire. The liquid in both cells becomes heated. In which is the rise in temperature the greater, and why?

13. The work done (or the heat generated) in the various parts of a circuit is proportional to the resistances of those parts when the current is of the same strength throughout; in the present case the current is of the same strength in both cells, because they are joined in series. Now, as in one of the cells under consideration, the plates are twice as far apart as those of the other cell, it will offer nearly twice the resistance; therefore the amount of heat liberated and the corresponding increase of temperature will be nearly twice as great in the cell with the plates far apart as in the other cell.

14. A gutta-percha covered copper wire is wound round a wooden cylinder AB from A to B. How would you wind it back from B to A (i.) so as to increase, (ii.) so as to diminish, the magnetic effects which it produces when a

current is passed through it? Illustrate your answer by a diagram drawn on the assumption that you are looking at the end B.

14. Supposing the first layer from A to B to be a right-handed helix, the second or return layer from B to A should be a left-handed helix to increase the electromagnetic effect which would result from a current flowing through the wire. If the return helix is also turned right-handedly (or if both are left-handed), then the effect of the current in one layer would neutralise the effect of that in the other. The essential feature in order to increase the effect is that the wire should

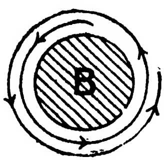

FIG. 30.

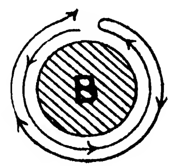

FIG. 31.

be wound on continuously without being bent back on itself. Fig. 30 illustrates the appearance of the end B for an increase in the effect, and fig. 31 for a diminution.

1890

MAGNETISM

1. A piece of steel wire, bent so as to form two sides of a square, is magnetised in such a way that each of its free ends is a north pole, and the bend a south pole. When placed on a cork floating in water, how will it set?

1. The wire will set itself so that the magnetic meridian passes through the south-seeking pole and midway between the two north-seeking poles, the south-seeking pole pointing of course to the south. In the diagram, fig. 32, N S represents the meridian.

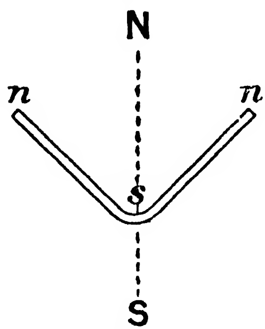

Fig. 32.

2. A rod of iron A B, held vertical with the end B downwards, is smartly tapped with a mallet. When turned into a horizontal position and brought near to a compass needle, the end B repels the north pole of the needle at a distance of four inches, but attracts it when the distance is reduced to one inch. Explain this.

2. When the iron is held vertically its position is approximately coincident with the lines of the earth's field, and it is consequently feebly magnetised, the lower end B being of north-seeking polarity. The smart tap sets the particles in vibration,

and the rod becomes more strongly magnetised under the influence of the same magnetising force. When presented horizontally at a distance of four inches, the north-seeking pole at the end B repels the north-seeking pole of the compass needle. But when the distance is reduced to one inch, the north-seeking pole of the compass needle induces sufficient south-seeking polarity in the end B to mask and overcome, or reverse the pre-existing polarity; hence attraction results.

3. A large soft iron rod lies on a table in the magnetic meridian, and a dipping needle is placed at some distance and at about the same level (i) due south, (ii) due north, of it. How will the magnitude of the angle of dip be affected in each case? (Neglect any inductive action between the needle and the bar.)

3. The bar of soft iron N S, fig. 33, being placed horizontally in the magnetic meridian, some of the earth's lines of force

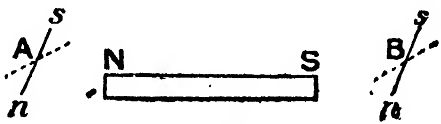

FIG. 33.

will pass lengthways through it. It will, therefore, be magnetised with its north-seeking pole pointing northwards, although the effect will not be so great as it would be if the bar were in a vertical position. Consequently (i.) its south-seeking pole S will attract the north-seeking pole, and repel the south-seeking pole of the dipping needle B, and will cause the angle of dip to be diminished, making the needle take up some such position as that indicated by the dotted line. Similarly (ii.) the north-seeking pole of the bar will repel the north-seeking pole, and attract the south-seeking pole of the dipping needle A, and will again cause a diminution in the angle of dip, making the needle take up some such position as that indicated by the dotted line.

4. A compass needle is deflected 15° from the meridian, when a bar magnet is placed on the table some distance

away. Will the deflection be altered if the poles of the magnet are connected by a bent iron rod? Give reason.

4. Let N S, fig. 34, be the magnetic meridian, *n s* the compass needle, $n_{,}\ s_{,}$ the bar magnet, and *a b* the bent iron rod.

The needle is first urged out of its position owing to the field set up by the bar magnet $n_{,}\ s_{,}$, the lines of force of which are approximately at right angles with those of the earth. When, however, the poles of $n_{,}\ s_{,}$ are connected by the bent

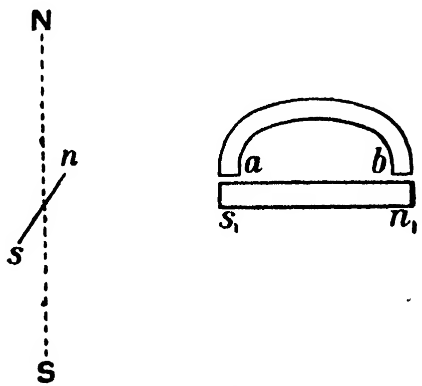

Fig. 34.

iron rod *a b*, the field of the bar is disturbed, and many of the lines will now pass through *a b*. Consequently the field in the vicinity of the needle *n s* will be very considerably weakened, and the needle will return towards the meridian.

FRICTIONAL ELECTRICITY

5. An insulated conductor A is charged with electricity. Another conductor B, earth-connected, is placed near to A. Is the induced charge on B greater than, equal to, or less than the charge on A? Give reasons for your answer.

5. In no case can a charge induce another charge greater than itself, but in every case the *total* induced charge is equal

to the inducing charge, although this total is only developed upon one conductor, when the conductor carrying the inducing charge is enveloped by the conductor upon which the induced charge is developed. In all other cases, including the one which is the subject of this question, the inductive effect is exerted upon all neighbouring bodies, including the walls of the room and the furniture, &c. contained therein. Therefore the charge, say +, on A, fig. 35, develops on the near surface of B an opposite or negative charge, but less in quantity than the charge on A; the difference between the two charges will depend upon the greater or less proximity of the two conductors, and upon the relative nearness or otherwise of other bodies.

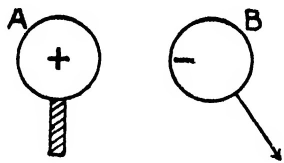

FIG. 35.

6. A glass rod is electrified by being rubbed with silk. A small sewing needle held in the hand is then passed along the rod from end to end, the point of the needle not quite touching the glass. What effect is produced, and how do you explain it?

6. The effect of passing the needle along the glass rod will be to neutralise its charge, more especially if care be taken to select a *thin* needle (because it has a finer point than a stout one), and if the needle be passed both up and down the rod on opposite sides. Under these conditions the neutralisation will be complete. This results from the fact that as the earth-connected needle passes along close to the glass it is under the inductive influence of the positive charge on the glass. It is therefore being continually endowed with a negative charge which, as fast as it is generated, escapes from the *pointed* needle on to the glass, and so neutralises the charge on the latter. When the point is blunt, the amount of electricity per unit area thereat is less, and the tendency to escape is less, so that neutralisation is then only partly effected. It may be noticed that an ordinary brass pin is not nearly so effective as

a fine needle, because of its thicker point. Of course in every case a quantity of positive electricity escapes through the hand to earth, equal in amount to the negative which goes to the glass.

7. An electroscope is surrounded by a cylinder of wire gauze which is put to earth. If an electrified body is brought near to it, how will the leaves behave? Give reasons for your answer.

7. This is a similar case to that dealt with in the answer to question No. 9 of 1886, the wire gauze taking the place of the cotton cloth, and, being also earth-connected, the electroscope will be effectively screened from the influence of the electrified body.

8. Two equal insulated uncharged spheres B and C are placed on opposite sides of and at equal distances from a charged sphere A. What is the electrical state of B and of C, and what will happen if the part of B nearest to A is connected by a fine wire with the part of C farthest from A?

8. Supposing the middle sphere A to be positively electrified, and the outer spheres to be unconnected, the inductive

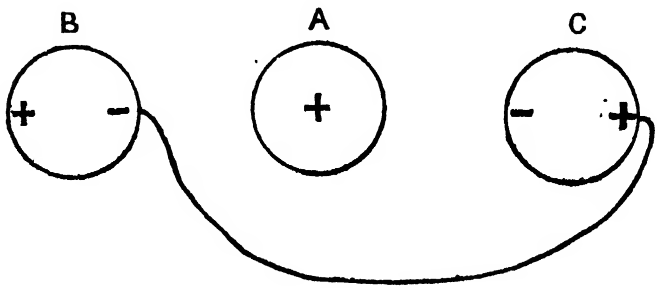

FIG. 36.

effect of A upon B and C will be equal, and the amount of negative developed on the near surfaces of each will therefore be the same. Similarly the amount of positive repelled to the remote surfaces of the two spheres will be equal. The effect

produced by connecting the two spheres by a wire, in the manner described, will depend entirely upon the length and disposition of the connecting wire. If the wire is short, so that its middle part passes near the sphere A, as in fig. 36, the state of affairs will remain practically unaltered, because the remote parts of B and C are still the most distant parts of the system with respect to A. If, however, the connecting wire be long, so that its middle portion is more remote than any part of B and C from the sphere A, the positive charges will be repelled from the outer spheres to the distant part of the wire, the negative remaining as before on the near parts of B and C.

9. A Leyden jar was twice charged and discharged. The first time the knob was held a quarter of an inch from the prime conductor of the electric machine; the second time the knob was in contact with the prime conductor. Both times the machine was worked for the same interval. In which case will the discharge spark be the brighter? Give reasons.

9. The discharge spark will be brighter when the jar is charged with its knob in contact with the prime conductor of the machine, because in that case the jar will be charged to a higher potential, and will contain a greater quantity of electricity than will be the case when the knob is held a quarter of an inch away from the prime conductor. The potential will be greater in the former case for the reasons stated in answering question No. 7 of 1889, and the quantity of the charge also will be greater, because the capacity of the jar being the same on both occasions, its charge will be directly proportional to the potential. The brilliance of the spark depends upon the amount of energy expended in the discharge, and this is proportional to the product of the potential difference and the quantity of electricity involved.

Looking at the matter from another point of view, if on both occasions the machine is made to give out the same amount of energy, it is evident that a considerable proportion thereof must be lost in the sparking which takes place to charge the

jar when its knob is held at a distance from the prime conductor, and the energy so lost is not, of course, available when the jar is discharged.

VOLTAIC ELECTRICITY

10. A strip of platinum and a strip of zinc dip into a vessel of acidulated water. How would you show that two copper wires fastened one to the zinc and the other to the platinum are in different electrical states?

10. This difference could be shown by connecting the zinc plate Z, fig. 37, by means of a wire W to an insulated copper plate A, and the platinum plate C to a second insulated copper plate B, and suspending between them a strip of gold leaf G. Supposing the gold leaf to be positively electrified, it would be attracted by the plate A and repelled by the plate B; but if negatively electrified, it would be repelled by A and attracted by B; thus showing A to be negatively and B positively electrified. The plates A and B being merely extensions of the wires W W are respectively in precisely the same electrical state, and therefore the same difference exists between the wires as between the plates.

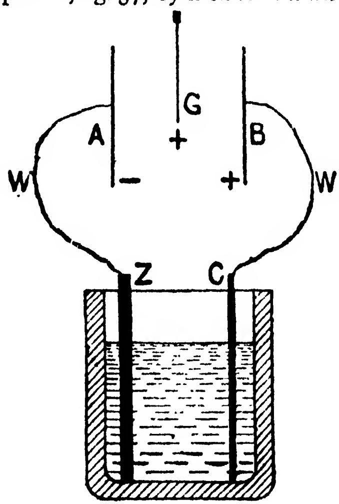

FIG. 37.

11. How would the action of a Daniell's cell be modified if the solution of copper sulphate in the porous vessel were replaced by dilute sulphuric acid?

11. This question is partly answered in solving question

No. 11 of 1888, where it is shown that when the sulphate of copper is exhausted, the chemical reactions take place through the acidulated water, and hydrogen is deposited as a gaseous film on the surface of the copper plate. In precisely the same way if a sulphuric acid solution be employed in place of the sulphate of copper solution, the action will be carried on through the acid solution, and hydrogen will be deposited. The liquid in the zinc division being also a sulphuric acid solution, we have, to all intents and purposes, a simple cell with zinc and copper plates immersed in sulphuric acid solution. The presence of the porous pot or partition does not affect the action in any degree whatever; it simply gives the cell a greater internal resistance than it would have in the absence of the porous pot.

12. Two long wires are placed parallel to each other in the same horizontal plane and in the magnetic meridian. A magnetic needle capable of turning in any direction about its point of suspension is placed exactly halfway between them. How will it behave if the same electric current flows through the easterly wire from south to north and through the westerly wire from north to south? (The action of the earth on the magnetic needle may be neglected.)

12. In this case the current in one wire will assist the current in the other wire to set the needle in a definite position. For if E and W, fig. 38, represent respectively the vertical sections of the horizontal wires to the east and west of the needle, then the 'positive direction' of the lines about E due to a current flowing from south to north will be right-handed, while those about W due to a current flowing from north to south will be left-handed, as shown in the figure. These lines are all in vertical planes, and as, between the wires, the lines are all upward, the needle in setting itself along these lines, or in such a position that the greatest possible number of them will pass through it for the greatest distance and coincide in direction with its own lines, must also place itself vertically with its north-seeking pole upward. It will then, of course, be at right angles with the wires.

[Such questions as these are best understood and answered by remembering that the positive direction of lines of force about a wire carrying a current is considered to be right-handed when looking along the wire in the direction in which the current flows; while the lines of force enter at the south-seeking pole and leave at the north-seeking pole of a magnet, that is to say, the positive direction is from south to north through the magnet, and from north to south in the air space outside the magnet. It is then only necessary to bear in mind that the

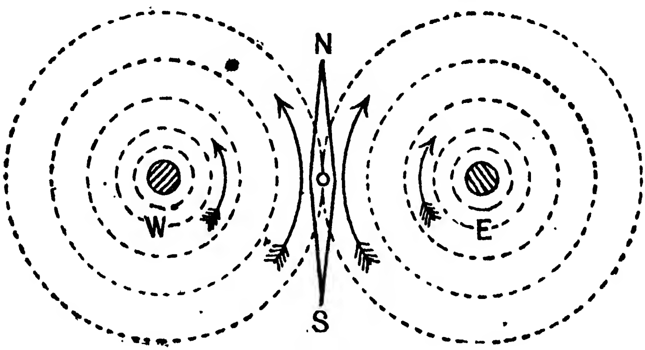

FIG. 38.

universal tendency for two or more sets of magnetic lines of force is to coincide in direction.]

13. Two copper plates of the same weight are connected, one with the positive and the other with the negative pole of a voltaic battery, and immersed side by side in a solution of copper sulphate. If, after some time, the plates are removed, dried, and re-weighed, they are found no longer to weigh alike. Account for this and explain how, by the continued action of the current, the equality of the plates could be re-established.

13. The plate in connection with the positive or copper pole of the battery will diminish in weight, while that in connection with the negative or zinc pole will increase by the same amount, so that the two together would at the end of the experiment weigh the same as at the commencement. The amount

of copper in the solution would remain unaltered. Let z c, fig. 39, be the battery and *a* and *b* the two copper plates immersed in the sulphate of copper solution. Then the current will pass in the direction indicated by the arrows. The solution will attack *a* and dissolve some of the copper. The copper thus dissolved will displace an equal amount of copper from the solution, which will be deposited upon the plate *b*. The reactions are represented by the equation

$$Cu + SO_4Cu + Cu = CuSO_4 + CuCu.$$

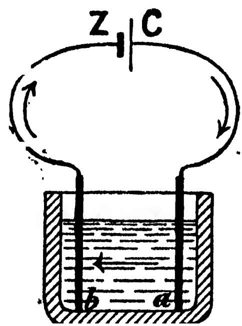

FIG. 39.

The amount of copper dissolved off *a* and deposited upon *b* will be proportional to the strength of the current and to the time during which that current is maintained. If, therefore, the equality of the plates is to be re-established, it can be accomplished by reversing the direction of the current, and taking care that it is maintained at the same strength and for the same time. If instead of reversing the direction of the current, the plates *a* and *b* were reversed or changed over, the same result would be arrived at.

14. One end of a coil of wire, through which a current passes, is found to attract the north pole of a compass needle, when placed at a certain distance from it. Will the action be the same (i.) in nature, (ii.) in amount, when a rod of soft unmagnetised iron is placed inside the coil?

14. A magnetic needle is deflected by a coil of wire carrying a current in virtue of the lines of force set up by the current in the wire and extending through the space occupied by the needle. The introduction of a rod or core of soft unmagnetised iron into the coil does not change the nature of the lines of force, but causes a far greater number to extend to a considerable distance from the wire generating them. In fact the iron

becomes a powerful magnet, magnetised similarly to the coil before its introduction, and consequently the needle remains deflected in the same direction as before; but as a far greater number of lines of force are now acting upon it, the magnitude of its deflection will be increased.

1891

MAGNETISM

1. A long magnet and a piece of soft iron of the same size and shape are placed parallel to each other underneath a sheet of paper upon which iron filings are strewed. How will the filings arrange themselves?

1. The bar of iron, *n s*, fig. 40, will be magnetised by the magnet with its opposite poles adjacent, although its magnetisa-

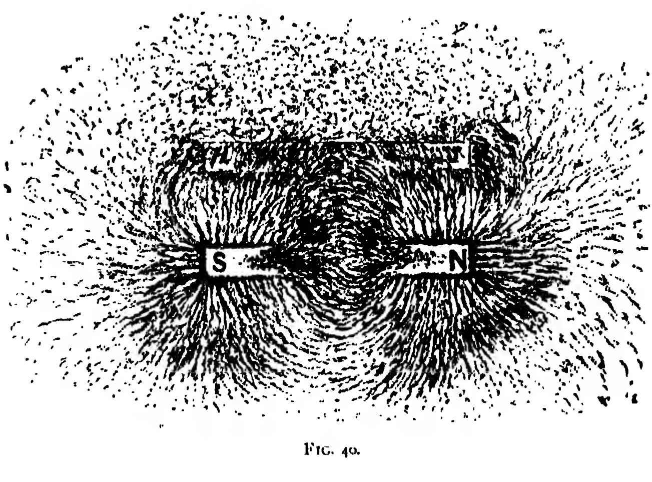

FIG. 40.

tion will be less than that of the inducing magnet N S. The way in which the iron filings arrange themselves is illustrated in the diagram. The difference in the disposition of the filings

on the outer sides of the iron bar and of the magnet respectively should be noticed. The effect of the iron is to afford an easier path for the passage of the lines of force in its vicinity than does the air, and the bar acquires its polarity in virtue of the lines of force which thus pass through it; so that the field on the side of the iron remote from the magnet is exceedingly weak—weaker, in fact, than it would be in the absence of the iron.

2. A tall iron mast is situated a little in front of the compass in a wooden ship. Explain the nature of the compass error when the ship is sailing in an easterly direction (i.) in the northern, (ii.) in the southern hemisphere.

Fig. 41.

2. A north-seeking pole will be induced by the earth's magnetism at the lower end of the mast when in the northern hemisphere, consequently the north-seeking pole of the compass needle will be repelled and will move towards the west as shown by the dotted line in fig. 41. The needle, fig. 42, will be deflected in the opposite direction when in the southern hemisphere, because the bottom of the mast will then be of south seeking polarity.

Fig. 42.

3. A rod of iron, when brought near to a compass needle, attracts one pole and repels the other. How will you ascertain whether its magnetism is permanent or is due to temporary induction from the earth?

3. In order to ascertain this, the iron rod should be held in a horizontal position pointing east and west, in which position the earth's magnetism could not sensibly magnetise it. If, therefore, while in this position, either end of the bar attracts one pole of the needle and repels the other pole, its

magnetisation is permanent, but if either end of the bar attracts either pole of the needle indifferently then its previous magnetisation was due to temporary induction from the earth.

4. Given a magnet and the means of suspending it, how will you determine (i.) the magnetic meridian, (ii.) in which direction north lies? It is assumed that you do not know which end of your magnet is a north and which a south pole.

4. The magnetic meridian can be determined by suspending the needle so that it can move freely in a horizontal plane. It will then under the influence of the earth's magnetic field take up a position in the magnetic meridian, pointing north and south.

If the magnet is properly balanced and suspended at its centre, the end pointing northwards will 'dip,' that is to say, in pointing directly to the north magnetic pole of the earth it will make an angle with the horizontal, and the end so pointing downward is the north-seeking pole of the magnet

FRICTIONAL ELECTRICITY

5. One end of a gutta-percha-covered copper wire is connected with an electrical machine, and the other dips into a non-conducting liquid. When the machine is worked the liquid is agitated. Explain this.

5. A convectional discharge will take place from the end of the wire dipping in the liquid, the non-conducting liquid acting in much the same way that air does under similar circumstances, that is to say, the particles in contact with the end of the wire will be highly electrified similarly to the wire, and consequently be repelled, their places being taken by other particles which are similarly treated. Hence the agitation.

6. Under what circumstances is it possible to transfer the whole of the charge on a conductor to another insulated conductor?

6. The *whole* of the charge can be communicated from one conductor to another insulated conductor, when the former is placed wholly inside the latter and made to touch it. For example, if the charged conductor were a sphere suspended by a silk thread, it could be entirely discharged by placing it inside an insulated metal pot, and allowing it to touch the bottom.

7. An insulated hollow metal vessel has a charge of positive electricity, and is at some distance from other conductors. An uncharged metal ball supported by a silk thread is (i.) introduced into the vessel without touching it, (ii.) connected momentarily with the earth, and (iii.) removed to a distance. State how its potential changes during these operations.

7. To begin with, the ball is unelectrified and at zero potential; when, however, it is placed inside the hollow metal vessel (fig. 43), it is raised to the same potential as the vessel, which is above that of the earth. If necessary this fact

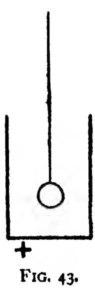

FIG. 43.

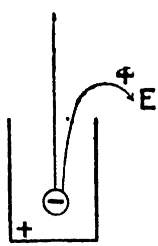

FIG. 44.

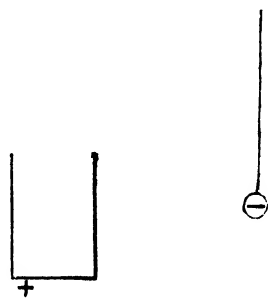

FIG. 45.

could be proved by connecting the vessel and the ball by means of a wire, when it would be found that no electricity would pass between them, thus showing them to be at the same potential. When, as in fig. 44, the ball is earth-connected, it is reduced to the earth's potential, a positive charge passing to earth and a negative charge being retained on the ball. The

passage of the positive charge to the earth proves that before the connection was made the ball was at a higher potential than that of the earth. When, as in fig. 45, the ball is removed, the negative charge is carried with it, and its potential then falls below zero, that is to say, below the earth's potential, and if it were earth-connected, a positive charge would flow to it from the earth to neutralise it and restore it to zero potential.

8. The ebonite portion of an electrophorus is charged with electricity. What means would you take to completely discharge it?

8. The charge can be completely dissipated by passing the ebonite disc through a flame.

9. Describe an experiment to prove that two points may have the same potential, though one is charged with positive electricity, and the other is either uncharged or charged with negative electricity.

9. Let A and B, fig. 46, be two unelectrified insulated conductors placed in contact, and let C be a charged insulated conductor placed near B. The positive charge on C will induce electricity in A and B, the negative being concentrated on the near side of B, and the positive repelled to the remote side of A. If a wire, connected at one end with the cap of an electroscope, be placed in contact with any part of either of the conductors A and B, a certain deflection of the leaves will be obtained, and this deflection will be reproduced when contact with any other part is made.

FIG. 46.

This proves conclusively that the conductors A and B are at a common potential. If, now, A be removed, it can be proved that it has a positive charge by the increased divergence obtained when it is placed in contact with a positively charged electroscope. Similarly, if B be removed from C and placed in contact with a negatively charged electroscope, the increased

divergence of the leaves which will ensue proves that B has a negative charge.

Had A been earth-connected while in contact with B and prior to its removal from the influence of C, the uniformity of potential would be maintained, and could be demonstrated, as before, by the electroscope, but in this instance no divergence of the leaves would take place, because every point of the two conductors would be at zero potential. But on removing A, this conductor would be found to be uncharged, and incapable, therefore, of communicating a charge to an electroscope. B would, however, still prove to be negatively charged.

VOLTAIC ELECTRICITY

10. A vertical partition of porous earthenware is fitted into a tumbler and dilute sulphuric acid is poured into each compartment. Rods of common zinc and copper are placed respectively in two compartments and connected by a wire. State what will be observed with regard to the evolution of gas, and how the observed phenomena will be modified when copper sulphate solution is poured into the compartment containing the copper rod.

10. With sulphuric acid solution in both compartments, the combination is in principle a 'simple cell,' in which the acid is gradually decomposed, the sulphur and oxygen uniting with the necessary proportion of zinc to form sulphate of zinc, which is dissolved in the liquid, no gas being evolved at the zinc plate. The remaining constituent of the acid, viz., hydrogen, is deposited in the gaseous condition on the surface of the copper plate, whence some of it escapes into the air in bubbles. When the liquid in the compartment containing the copper rod is a sulphate of copper solution, the combination becomes a Daniell cell. The sulphate absorbs the hydrogen liberated by the action between the zinc and sulphuric acid, and the copper which is displaced by the hydrogen is deposited in a metallic state upon the copper rod. There is, therefore, no gas evolved at either plate in such a cell.

11. A current is flowing through a rigid copper rod. How would you place a small piece of iron wire with respect to it so that the iron may be magnetised in the direction of its length? Assuming the direction of the current, state which end of the iron will be a north pole.

11. The lines of force developed by a current take the form of circles which have the axis of the conductor for a common centre, after the manner illustrated in fig. 38. In order to magnetise a piece of iron by the field thus set up, the iron should, as nearly as possible, coincide with the direction of these lines, that is to say, the iron should be at right angles with the rod. The positive direction of a line of force is defined as the direction in which a free north pole would be urged along it, and this direction can, in cases like that under consideration, be easily predicted by the method described in the solution to question No. 12 of 1890. It will be observed that if the piece of iron wire, N S, fig. 47, be placed horizontally behind the vertical conductor through which the current is flowing upwards, it will be magnetised, so that the end to the left becomes a north pole.

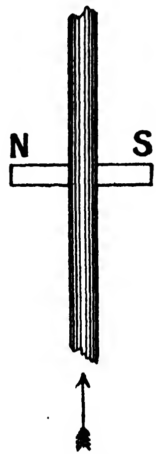

FIG. 47.

12. A circuit includes an insulated battery and a galvanometer. Will the indication of the galvanometer be affected if a point in the circuit (e.g. the negative pole of the battery) is directly connected with the earth? Give reason for your answer.

12. When any point in an otherwise insulated circuit, through which a current is passing, is put direct to earth, that point is at once brought to the earth's potential, but the total fall of potential round the circuit remains the same, as does also the relative potential difference between any two points in the circuit. Consequently the current strength remains unaltered, and there is then no alteration in the indication of the galvano-

meter. To effect any alteration it would be necessary to connect at least two points in the circuit with the earth.

13. The poles of a battery are connected by a long wire. Of this, two lengths of 6 inches, one near the positive pole, the other halfway between the poles, are immersed in two similar vessels of water. Will there be any difference in the amounts of heat produced in the two? Give reasons.

13. The amount of heat developed by a current depends upon the strength of that current, and upon the resistance of the conductor through which it is flowing. That which is true of the circuit as a whole is correspondingly true of the various parts of a circuit. In the case under consideration both lengths of wire form part of the same simple or undivided circuit, and consequently the current strength is the same in both. Both form parts of the same wire, and have therefore the same sectional area, and both are of the same length; therefore both have the same resistance. As both lengths of wire carry the same current, and both offer the same resistance, the same amount of heat will be developed in both, that is to say, there will not be any difference in the amount of heat produced in the two vessels.

14. A hundred Grove cells are arranged in series, and wires attached to their terminals are momentarily brought into contact with the inner and outer coatings of a Leyden jar. What result will follow if the operation of discharging the jar is afterwards performed? Give reasons for your answer.

14. The potential difference at the terminals of a battery of 100 Grove cells joined in series is about 190 volts, and if wires are connected from these terminals to the inner and outer coatings respectively of a Leyden jar these coatings will be raised to the same potential difference, the charge which the jar thus obtains being proportional to its capacity. If the jar be discharged in the ordinary way, the two coatings will be restored to a common potential, that is to say, the positive and negative charges will neutralise, and the discharge will be

accompanied by a short spark. The length of such a spark depends upon the potential difference between the coatings, and when charged from an electrical machine, a potential difference of several thousand volts is usually established. With 10,000 volts the spark would be approximately one inch long. In the present case, the potential difference being comparatively low, the discharge spark would be correspondingly short and feeble.

1892

MAGNETISM

1. Two bar magnets are laid on a table at right angles to each other, so that the axis of one passes through the middle point of the other. They do not touch. A sheet of cardboard over which iron filings are uniformly scattered is placed above them and tapped. Draw a picture showing the appearance which the filings present.

1. The arrangement of the filings is illustrated in fig 48. They manifest the usual tendency to set themselves in curved lines connecting opposite magnetic poles together, no matter whether the opposite poles belong to the same magnet, or two different magnets. There is also clearly shown the manner in which the sets of lines of force emanating from or passing into two adjacent but similar poles appear to repel or glance off from one another.

2. An iron rod held vertically is tapped with a mallet. The upper end is found to repel the south pole and attract the north pole of a compass needle. The rod is now quietly inverted, and the same end (which is now the lower) is tested again. It is then tapped and once more tested. State what results you would expect, and explain them.

2. When the rod is held vertically it lies approximately in the same direction as the lines of force due to terrestrial magnetism, and the tapping sets the particles into sufficient vibration to enable the rod to become more or less permanently magnetised, with a north-seeking pole at the lower end and a south-seeking pole at the upper end. Consequently the upper

end repels the south-seeking pole and attracts the north-seeking pole of the needle. On quietly inverting the rod it retains at least a portion of its magnetisation, and that which is now the lower end still, although perhaps more feebly, repels the south-seeking pole and attracts the north-seeking pole of the

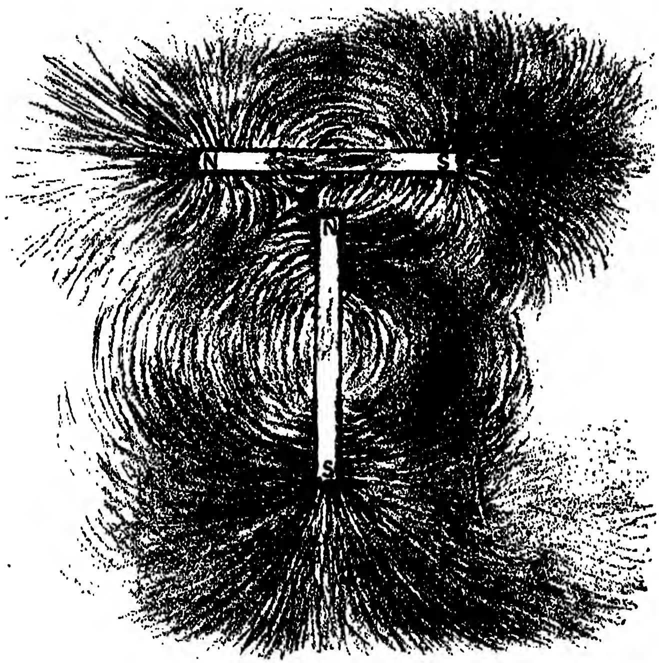

FIG. 48.

compass needle. The tapping enables the particles to reverse themselves under the influence of the earth's magnetism, and thereby to reverse the magnetisation of the rod, so that the upper end again repels the south-seeking pole and attracts the north-seeking pole of the needle.

3. It is suspected that a magnetised bar of steel has consequent poles. How would you ascertain whether this is so or not?

3. There are several ways by which the existence or otherwise of consequent poles can be ascertained. One method is to test the bar by bringing various parts along its length near one pole of a compass needle, and observing the result. Another method is to place it in iron filings, when the existence of one or more consequent poles would be made evident by accumulations of filings at these parts. Perhaps the best method, however, is to place the bar of steel under a sheet of paper and sprinkle iron filings over the paper. The existence of consequent poles would be clearly indicated by the passage of a considerable number of lines of force, into and out of the bar at other points besides its ends.

4. A dipping needle can oscillate in the magnetic meridian. A long bar of soft iron held horizontally in a north and south direction is brought near to it from the south. How is the inclination of the needle to the horizon affected as the distance between it and the bar is gradually diminished?

4. The soft iron bar (fig. 49) will, under the influence of terrestrial magnetism, be feebly magnetised with a north-seeking pole at the approaching end. Consequently the south-seeking pole of the dipping needle *s n* will be gradually drawn down or the angle of dip diminished as the bar approaches. Ultimately the needle will lie horizontally, the attractive effect being increased by the inductive action of the south-seeking pole of the needle upon the near end of the bar.

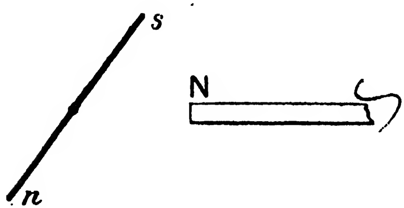

Fig. 49.

FRICTIONAL ELECTRICITY

5. How would you show experimentally that when a charged conductor is introduced into the interior of another conductor without touching it, the charge induced on the external conductor is equal to the inducing charge?

5. The fact that the induced charge is under these conditions equal to the inducing charge can be readily demonstrated. Let the insulated charged conductor be lowered well into the larger hollow conductor (care being taken to prevent contact between the two conductors). An opposite charge will be induced on the inside, and a similar charge on the outside of the external conductor. If the latter is now momentarily earth-connected, this similar charge will escape to earth, leaving on the outer conductor only the opposite charge on the inner surface. The fact that the two conductors are now charged can be proved by withdrawing the inner one and applying the two separately to an electroscope. Let the smaller conductor then be replaced in the larger one, but let the two now touch each other. It will be found that the contact has fully discharged both the conductors, proving thereby that the charges were opposite, and that they were also equal.

We also know that the similar charge which escaped to earth was equal to the opposite charge which remained in the hollow conductor, and the latter charge was equal to that on the inner conductor, therefore the three charges were equal.

6. Four precisely similar insulated metal balls, A, B, C, D, are placed in a row. The two inner balls (B and C) are in contact, and the distances A B and C D are equal. If A and D are electrified, what will be the electrical states of B and C after first one and then the other has been removed from the neighbourhood of A and D; (i.) when the charges on A and D are equal and opposite; (ii.) when the charges are equal and similar?

6. In the first case, fig. 50, when the charges on A and D are equal and opposite, say + and − respectively, these charges will assist each other in inducing a charge of negative on B, and one of positive on C. On removing B it will be found to retain its negative charge, and similarly on removing C it will be found to have a positive charge equal to the negative on B.

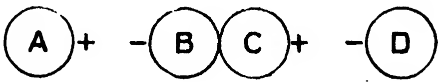

FIG. 50.

In the second case, however, fig. 51, the two similar charges, say of positive, on A and D will develop comparatively smaller negative charges on the outer portions of B and C, the corresponding positive charges being repelled to the inner portions, or those parts which are in contact. On the removal

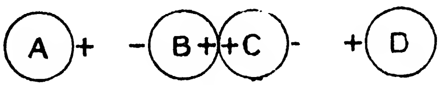

FIG. 51.

of B, the two equal charges will reunite, and the ball will appear to be unelectrified. Similarly, when C is removed all trace of electrification will disappear.

Some little difficulty may be experienced in performing these experiments, owing to the difficulty first of obtaining the four balls of precisely equal diameters; secondly, of making sure that the distances A B and C D are exactly equal; and thirdly, that the charges on A and D are likewise equal.

7. A pad of flannel is placed at the bottom of a metal vessel which is insulated and connected by a wire with the cap of a gold-leaf electroscope. One end of a long rod of sealing-wax is now rubbed against the flannel. What indications will the electroscope give, (i.) while the rubbing is going on; (ii.) when the sealing-wax is withdrawn?

7. When the rod of sealing-wax is rubbed on the flannel

pad, both will become equally and oppositely electrified. While the rubbing is going on, negative will be developed on the sealing-wax and positive on the flannel, but the electroscope will not be affected, because the negatively electrified sealing-wax prevents the positive electricity developed on the flannel escaping to the outside of the vessel and the electroscope.

When, however, the sealing-wax is withdrawn, the positive on the flannel will, owing to the flannel being a fairly good conductor, be distributed over the outside of the metal vessel and the electroscope, whence the leaves of the latter will diverge.

8. A positively electrified body is brought in turn into the neighbourhood of (a) an insulated unelectrified conductor; (b) an earth-connected conductor. How is the potential of the unelectrified conductor affected in each case?

8. The insulated unelectrified conductor is initially at the earth's or zero potential, but when a positively electrified body is brought near it, its potential is raised, so that if it were then connected to earth, a positive charge would flow from it to the earth.

When, however, the unelectrified body is earth-connected prior to the approach of the charged body, no difference can be made in its potential, because all earth-connected bodies remain under all circumstances at the earth's or zero potential.

9. Two gold-leaf electroscopes, similar in all respects except that a needle projects from the cap of one of them, are placed at equal distances from an electrical machine. When the machine is worked both pairs of leaves diverge. When it ceases to work one pair of leaves collapses rather quickly, and the other pair very slowly. Explain this difference in their behaviour.

9. Both pairs of leaves will diverge freely while the machine is being worked, positive being repelled to the leaves and negative attracted to the cap in both cases. The

negative charge will be dissipated by convection from the point of the needle attached to the one cap, so that that electroscope will, after a short time, contain a positive charge only ; the negative will, however, remain on the cap of the other instrument. When the machine ceases to work, the pair of leaves contained in the electroscope without the needle will at once collapse, on account of the positive and negative recombining and neutralising. But the electroscope to which the needle is attached will remain positively charged, and its leaves will therefore collapse slowly as the charge is dissipated from the point of the needle.

VOLTAIC ELECTRICITY

10. Describe and sketch an electric bell which continues to ring as long as the circuit is closed.

10. The question is somewhat indefinite, and it is assumed that the description is required of a bell which continues to ring as long as the wires or springs, by which the circuit is first closed, are kept in contact. Fig. 52 illustrates the ordinary electric trembler bell and its connections. B represents a battery cell, usually of the Leclanché type, and P represents a push consisting of a pair of flat springs, which are usually pressed together by means of a small button of bone or other material. C and D are two terminals on the wooden base of the bell, and are connected to the push and battery in the manner illustrated in the diagram. Assuming the push to be depressed and the current to enter at the terminal D, the current passes to a brass pillar, and thence through the platinum-tipped screw E to the spring F, carried by the soft iron armature A. This armature is carried by a short and rather stiff spring G fixed in the metal framework, the other end of the armature carrying a rather long piece of wire furnished at its extremity with a brass ball or hammer H. The current leaving the spring F passes through G to the framework, and thence through the electromagnet coils K K to the terminal C, thereby completing the circuit

through the bell. The coils K K are furnished with soft iron cores, which are yoked together by the piece of soft iron L, and when the current passes through these coils the armature A is attracted. This causes H to strike the bell M, but the instrument is so adjusted that when A is thus attracted, the spring F leaves the screw E, and thereby opens or disconnects the circuit ; whence A ceases to be attracted, and is withdrawn by the spring G, so that F again touches E ; the circuit is again closed, and the current again passes, re-magnetising the coils K K, and causing the hammer H to again strike the bell. These operations being automatically repeated, the bell continues to ring as long as the springs in P are pressed together.

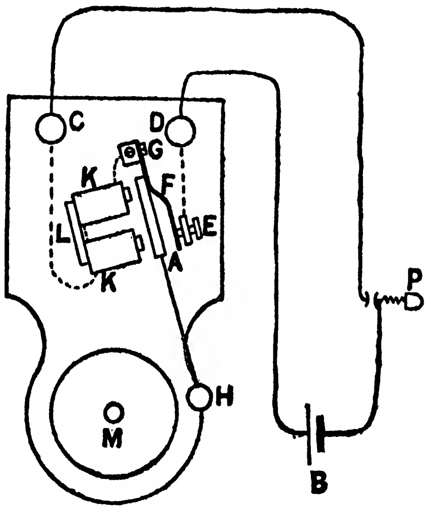

FIG. 53

11. A strong electric current flows through a copper wire which passes through the centre of an iron ring, and is at right angles to the plane of the ring. Describe the magnetic state of the ring.

11. When a current passes through a wire it sets up a mag-

netic field around it, the lines of force taking, unless prevented from so doing by the proximity of an irregular mass of iron, the form of concentric circles, and having the axis of the wire for a common centre. In the case in question the iron is symmetrically disposed in relation to the wire, and the majority of the lines of force developed in the neighbourhood of the ring will pass through it and round it. Its various particles will therefore be magnetised; but as these particles are so directed as to form continuous chains or circles, there will not be any external evidence of magnetisation at any part of the ring, and it will to all appearance remain unmagnetised. If, however, the ring be broken at any part, the two ends will exhibit magnetic polarity, one north-seeking and the other south-seeking, the strength of the poles depending principally upon the strength of the current.

12. Plates of copper and of platinum are dipped into a solution of copper sulphate, and a current is passed through the cell from the copper to the platinum. Describe the effects produced; also what happens when the current is reversed.

12. The current in passing through the cell (see fig. 53) from the copper to the platinum plate will gradually dissolve the former, but for every atom of copper thus dissolved one atom of copper will be deposited upon the platinum plate. The amount of copper in the solution remains therefore unaltered, but the platinum is gradually covered with a film or deposit of copper, and the amount of copper thus deposited is exactly equal to the amount dissolved off the copper plate.

When the current is reversed the coating of copper is dissolved off the platinum, and, entering the solution, a corresponding quantity is deposited upon the copper plate. If, however, the current is maintained after all the copper has been dissolved from the platinum, the sulphate of copper is decomposed, and copper continues to be deposited on the copper plate, but the copper sulphate solution now becomes proportionally weaker. The SO_4 released from the sulphate ($CuSO_4$) decomposes the water, and combines with the hydrogen to

form sulphuric acid, the oxygen of the water being liberated in the gaseous form. The liquid is thus in time changed from a copper sulphate to a sulphuric acid solution, and when that has been accomplished oxygen only is liberated at the platinum plate and hydrogen at the copper plate.

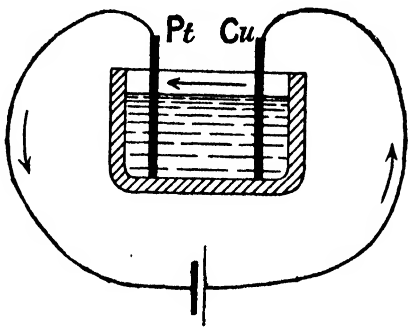

FIG. 53.

13. It is intended to set up 100 Grove's cells in series, but by mistake 10 cells are arranged in opposition to the rest. What is the relation of the potential difference of the terminals on open circuit to that which would have been obtained if the mistake had not been made?

13. When the whole of the 100 cells are properly joined up the potential difference of the battery on open circuit is equal to the sum of the potential differences of all the cells, that is to say, if their potential differences are equal, the potential difference of 100 cells is equal to that of 100 times the potential difference of one cell. Should, however, some of the cells be joined up in opposition to the rest, the resulting potential difference is equal to the potential difference of the cells properly joined up minus the potential difference of the cells joined up in opposition. In this case 10 of the cells are joined up in opposition, so that instead of getting a potential difference of 100 cells, we have only that of 90 − 10, that is to say, of 80 cells.

14. Explain the advantages of the astatic galvanometer in the detection of weak currents.

14. In an astatic galvanometer there are two magnetic needles as nearly equal in magnetic strength as they can conveniently be made. These needles are rigidly fixed together, but at a short distance apart, say three quarters of an inch, and they are so fixed that their similar poles point in opposite directions. Consequently when the combination is freely suspended the north magnetic pole of the earth acts with almost equal force upon both ends of the combination, and the value of the resultant tendency to make the needles set themselves along the magnetic meridian is simply dependent upon the difference between the magnetic strength of the two needles. The more nearly they approach to equality of magnetic strength, therefore, the less is the force exerted to prevent their being deflected from the meridian. In a galvanometer with an astatic pair it is usual to place the coil of wire round one of the needles, and this disposition of the wire has an important effect. The wire between the two needles tries to deflect them both in the same direction, the current passing, say, from south to north over one of them, and from north to south under the other. It follows, therefore, that the force due to the earth is reduced, while the force due to the current is increased, and these two facts consequently conspire to render an astatic galvanometer more sensitive than one with a single needle, or to cause a larger deflection with a given current. It is easy to conceive that a current which may be so weak as to be incapable of producing any perceptible deflection on a galvanometer with a single needle may yet be capable of producing a considerable deflection when an astatic pair is substituted for the single needle.

1893

MAGNETISM

1. A horseshoe magnet lies flat on a sheet of brass which is supported by strings in such a way that it turns about a vertical axis, but always remains horizontal. How will it place itself?

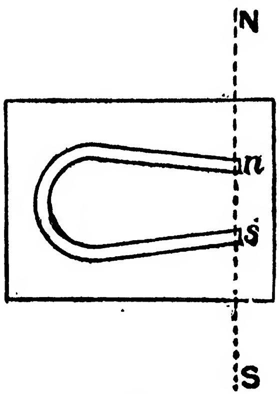

Fig. 54.

1. The magnet (fig. 54) will so place itself that its magnetic axis, that is to say the line connecting its poles *n s*, will lie in the magnetic meridian N S, with its north-seeking pole pointing northwards.

2. A compass needle, when disturbed from the magnetic meridian, makes a certain number of vibrations per minute in a horizontal plane. Would you expect it to vibrate more or less rapidly (i.) at the magnetic equator, (ii.) near the north magnetic pole, than at some intermediate place? Give reasons for your answers.

2. The rapidity with which any particular suspended magnet vibrates when disturbed from its position of rest, depends upon the strength of the field in which it is placed, or, more correctly speaking, it depends upon the strength of that part

of the field which can act effectively upon it in urging it back to the zero position. In the case of a compass needle, the horizontal component only of the earth's magnetic field so acts upon the needle, and as the horizontal component is greatest at the magnetic equator and becomes nothing at the north magnetic pole, the needle will oscillate with the greatest rapidity at the magnetic equator, and less and less rapidly as it is brought nearer to the north magnetic pole. It should be remembered that although the total magnetic force due to the earth is greater nearer the north magnetic pole, yet the proportion acting in a horizontal plane is so much less that the actual value of the horizontal component becomes less near the pole than towards the equator.

3. A bar magnet is laid on a table perpendicularly to the magnetic meridian, and so as to point to the centre of a compass needle. Describe and explain the behaviour of the needle.

3. Let A B, fig. 55, be the direction of the meridian, N S the bar magnet laid on the table at right angles with the magnetic meridian, and pointing to the centre of the compass needle

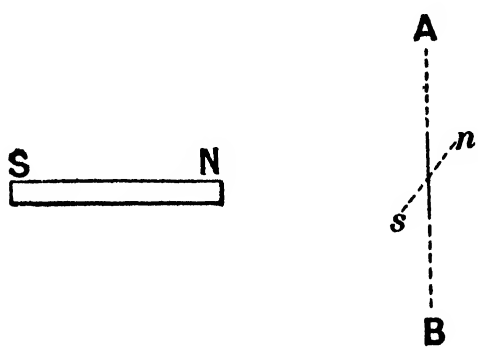

FIG. 55.

n s. The north-seeking pole of the magnet will attract the south-seeking pole of the needle, and repel its north-seeking pole; consequently its north-seeking pole will be deflected to the east as shown in the figure.

4. A bar magnet, which has two consequent poles at its middle point, is broken into two pieces. What will be the magnetic condition of each piece according as the break is made exactly at the middle point or at some distance from it?

4. As far as can be gathered from the question, the arrangement of the poles in the bar will be similar to that depicted in fig. 56, where the two adjacent south-seeking poles act together as one pole. If such a magnet be broken exactly at the middle, we shall get two simple magnets, each with a north-seeking pole

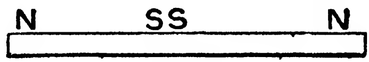

FIG. 56

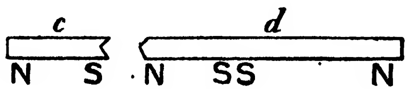

FIG. 57

at its original end, and a south-seeking pole at the fractured end. If the magnet be broken as shown in fig. 57, then the part *c* will be a simple magnet with north- and south-seeking poles. The part *d* will remain a magnet with consequent poles.

FRICTIONAL ELECTRICITY

5. Discuss the analogies between differences of level, temperature, and electrical potential respectively.

5. When two vessels, each containing water or other liquid, are connected together, and the surfaces of the water are at different levels, the water will flow out of the one vessel into the other, until the two surfaces are at the same level. The two vessels become, when connected together, to all intents and purposes one vessel, so that it is as difficult for the water to remain at different levels as it would be for one portion of the water contained in a single vessel to remain at a higher level than the rest of the liquid. A difference of level competent to set up

such a flow of water from the place where it is at a higher, to the place where it is at a lower level, can be established in a variety of ways. For example, if one vessel be raised above the other, the surface of the water in the former will be at a higher level than that in the latter; or, again, if two vessels of equal capacity, but of different shapes, one being taller and narrower than the other, and both containing the same quantity of water, be placed upon the table, the surface of the water in the narrower vessel will be at a higher level than that in the other vessel, and if the two be connected, water will flow from the former to the latter, until their surfaces are at the same level. It is also possible to cause water to flow from the vessel containing a less quantity into the one containing more, by adopting any convenient means for making the surface of the water in the former higher than that in the latter. It can thus be shown that it is the difference of level which determines the direction of the flow of the water, and not the difference of quantity.

Similarly, if two bodies at different temperatures are connected together by a good conductor of heat, or if one of them be placed inside the other, heat will pass from the hotter to the cooler until a common temperature is attained, and the magnitude of the effort to bring about this equality will be proportional to the difference of temperature, and this effort, as well as the direction of the flow of heat, will be independent of the relative quantities of heat contained by the two bodies.

If equal quantities of electricity be communicated to two insulated conducting spheres of equal dimensions, they will both be raised to the same potential, and if they are electrically connected together, nothing will happen, the two charges remaining on their respective spheres. Were one of the spheres to be larger than the other, a greater quantity of electricity would be required to raise it to the same potential as the smaller sphere. Its capacity is in fact greater, and when equal quantities of electricity are communicated to the two dissimilar spheres, the increase of potential in the larger sphere is less than that in the smaller one. Consequently, when the two spheres are connected together, electricity will flow from the smaller sphere, or the one which has the higher potential, to

the larger sphere, until the two attain the same potential. The magnitude of the effort in this case also will be proportional to the difference of potential.

It will thus be seen that the analogies between differences of level, temperature, and electrical potential, are very close.

6. How do you explain the fact that a Leyden jar cannot be highly charged unless its outer coating be earth-connected?

6. A Leyden jar can be charged to the maximum extent possible with the machine available, without its outer coating being earth-connected, provided the rubber of the machine be joined directly to the outer coating, while the prime conductor is connected to or brought near the inner coating. Under ordinary circumstances, however, the rubber of the machine is directly connected to earth, and if the outer coating of the jar is insulated from the earth, this coating is then entirely disconnected from the rubber of the machine.

Or, looking at the matter from another point of view, it should be remembered that the charge which can be given to a Leyden jar depends upon the potential difference which can be established between its inner and outer coatings, and upon the capacity of the jar. The capacity is proportional to the dimensions of the surfaces of the two tinfoil conductors, and to their relative nearness, or the thinness of the insulator (glass) separating them. When the outer coating of tinfoil is insulated it becomes practically inoperative, and the inner coating forms one conductor, the outer being the table or floor and other earth-connected conductors in the vicinity. These conductors are separated from the inner tinfoil conductor by a considerable distance, and the capacity of the jar, therefore, becomes enormously reduced in value. Consequently a very small charge imparted to the inner coating brings the potential up to the same value as that of the prime conductor, and no further charge can be imparted to the jar. On connecting the outer tinfoil to earth, however, the jar at once assumes its maximum capacity, the potential falls, and a further and much greater charge can be communicated to it under the same difference of potential.

7. An insulated brass ball without charge is hung near a negatively charged conductor. It is then momentarily connected with the charged conductor. Is its potential altered thereby, and if so, how? It is then momentarily connected with the earth. How does this affect its potential?

7. Let A, fig. 58, be the insulated brass ball without charge, and B the negatively charged conductor. The proximity of A to B will cause induction to take place in the former, the side nearest to B being positively electrified, and the remote side negatively. The potential of B is below that of the earth, and A is therefore made to assume a lower potential than the earth, although not so much lower as B. As A approaches B its potential is continuously lowered until, the moment of contact being reached, A gives up its positive to neutralise a portion of the negative on B. The potential of B is, therefore, raised, or made less below that of the earth than before. But A and B being in contact will assume a common potential, and this potential will still be below that of the earth. The difference between the potential of A and the earth will depend upon the size of B, and also upon the quantity of electricity it contained prior to the contact. On the ball A being again insulated and then earth-connected it will assume the earth's or zero potential, that is to say, it will be raised to the potential of the earth by a quantity of electricity flowing to it from the earth.

FIG. 58.

8. A hemispherical metal bowl, to which a short metal point is attached, is charged with electricity. What difference, if any, in the rate of loss of electricity will there be according as the point is fastened to the concave or the convex side of the bowl?

8. When the point is attached to the inner or concave side of the bowl, it will make no difference in the rate of loss of electricity, owing to the fact that if the point is well inside the bowl, the whole of the charge will remain on the outer surface of the bowl, and there will be no charge on the point.

But when the metal point is connected to the outside, some

of the charge will be distributed over it; in fact the density of the charge will be greatest at the point, from which the electricity will stream off readily in the form of a convection discharge, so that under these circumstances the rate of loss of electricity will be a maximum.

9. Faraday constructed a large wooden box, coated inside and outside with tinfoil, and insulated by means of glass supports, in which to make experiments on electricity. Suppose that inside such a box a man turns an electrical machine, the rubbers of which are connected to the inside tinfoil of the box, while the prime conductor is connected to the knob of an insulated gold-leaf electroscope, which is also within the box. Suppose also that the outside tinfoil is connected with another insulated electroscope outside the box. How will each electroscope be affected? Give reasons for your answers.

9. Let A, fig. 59, be the insulated wooden box coated on its inner and outer surfaces with tinfoil, B the machine, C the rubber connected with the inside of the box, D the electroscope connected with the prime conductor, and E the insulated electroscope connected with the outside of the box.

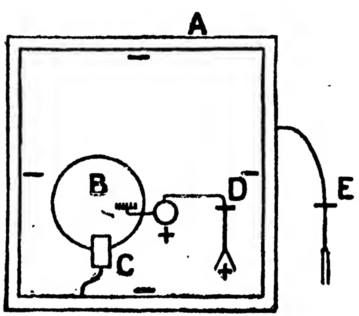

Fig. 59.

To begin with, the whole arrangement is unelectrified, and the leaves of both electroscopes therefore are unaffected. When the machine is worked equal quantities of positive and negative electricity are produced, the former accumulating on the prime conductor and electroscope D, the leaves of which will therefore diverge; and this positive charge will hold the whole of the equivalent negative charge on the inner surface of the box, so that the outer electroscope E will remain unaffected.

VOLTAIC ELECTRICITY

10. Describe an experiment which shows that in the charging of a condenser by contact of its plates with the poles of a strong battery there is a current of electricity. Explain why this current is only momentary.

10. If a sensitive galvanometer, the coils of which consist of many turns of wire, be inserted between either pole of the battery and its side of the condenser, the flow of a current at the moment of making contact between the battery and the plates will be made manifest by a brief deflection of the galvanometer needle. The current of electricity is only momentary, because the two sides of the condenser will be almost instantaneously brought to the same difference of potential as that between the poles of the battery itself, and the glass or whatever other material may be employed to separate the metal plates, is a sufficiently good insulator to prevent the flow of a continuous current of any appreciable strength from one plate to the other.

11. How would the substitution of dilute sulphuric acid for strong nitric acid in a Grove cell affect (i.) the value, (ii.) the constancy when working, of its E.M.F.?

11. The substitution of dilute sulphuric acid for strong nitric acid would convert a Grove cell into a simple cell with zinc and platinum plates immersed in dilute acid, but with the disadvantage that the resistance of the cell would be increased by the presence of the porous pot or partition. The electromotive force of such a cell would be considerably lower than that of a Grove cell supplied with the proper solutions, but it would be somewhat higher than that of a simple cell with zinc and copper plates. The constancy of the electromotive force would be materially impaired, because there would be no depolarising solution, that is to say, there would be nothing to take up the hydrogen released from the sulphuric acid, and the gas being deposited on the platinum plate, the cell would soon polarise and the electromotive force fall accordingly.

12. An electric current (which is the same in all parts of the trough) flows horizontally in a trough filled with copper sulphate. A rod of copper is then supported horizontally in the trough, with its length parallel to the direction in which the current is flowing. How will the rod be affected by the current?

12. Let A B (fig. 60) be the electrodes by which the current enters and leaves the solution contained in the trough, and let R C be the rod of copper supported horizontally in the solution with its length parallel to the direction in which the current is flowing. Owing to the considerably higher conductivity of the copper rod as compared with the solution, nearly all the current on leaving the positive electrode A will make for

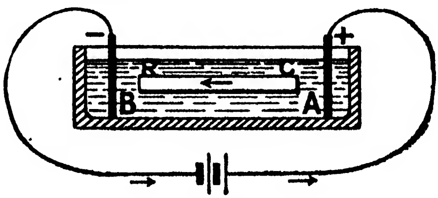

FIG. 60.

the rod R C, and will pass along the latter rather than through the solution. It will then leave by the end R and pass across the solution to the plate B. At the end C, where the current enters, particles of metallic copper will be deposited, but an equal quantity of metal will be dissolved from the end R, where the current leaves the rod, so that the weight will remain unaltered.

13. A wire is stretched over the centre of a magnetic needle perpendicularly to the magnetic meridian. The ends are then joined to the poles of a battery, so that a current flows from west to east through the wire. What is the effect, if any, on the position and circumstances of the needle?

13. Let N S (fig. 61) represent the magnetic meridian passing through the centre of the magnetic needle *n s*, and let

W E represent the direction in which the current is flowing over the needle. In this case the needle will remain in its original position, because that position is the one towards which it

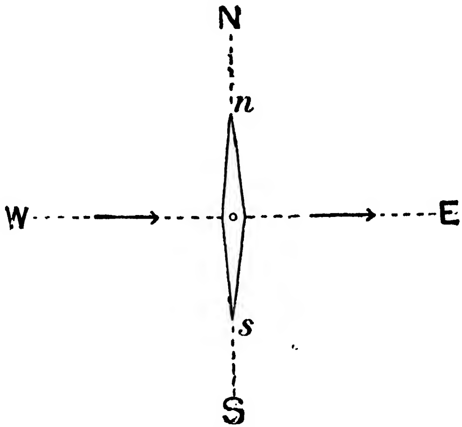

FIG 61

would be urged by the current, were it placed in any other position. In fact the lines of force due to the current and passing through the needle coincide with those due to the earth, so that a greater force would be required to deflect the needle than would in the absence of the current be necessary.

14. A current of electricity is passed through a long coiled conducting wire. Draw a diagram illustrating the form and directions of the lines of force within and without the coil.

14. The direction of the lines of force for a coil of four convolutions is depicted in fig. 62, where the convolutions are spread out in order to more clearly show the arrangement. The piece of cardboard on which in the experiment to obtain this figure the iron filings were sprinkled, was placed horizontally, and the wire threaded through it, so that the axis of the coil lay in the plane of the cardboard.

1894

MAGNETISM

1. A piece of cardboard is placed over a horseshoe magnet lying on a table, and iron filings are scattered over it. Draw a picture showing the arrangement assumed by the filings when the cardboard is tapped. If the poles of the magnet are joined by an iron keeper, how will the arrangement of the filings be modified when the cardboard is again tapped?

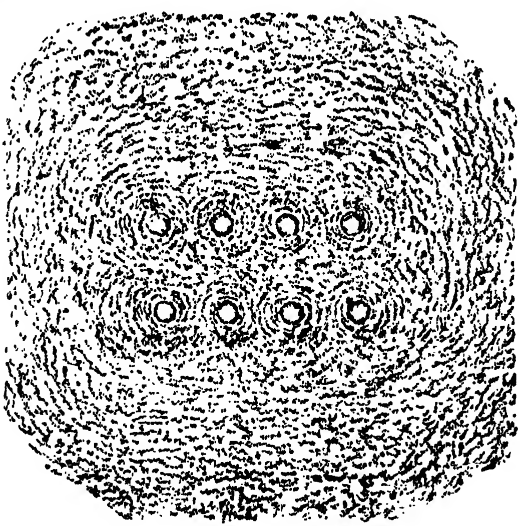

FIG. 62.

1. The arrangement assumed by iron filings sprinkled on a piece of cardboard placed over a horseshoe magnet lying on

a table is illustrated in fig. 63. Many of the lines of force extend to a considerable distance from the magnet, and cause the filings to arrange themselves along definite curved lines;

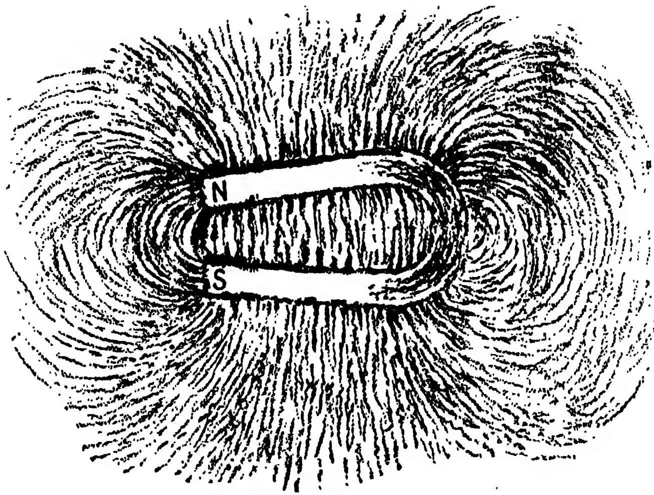

FIG. 63.

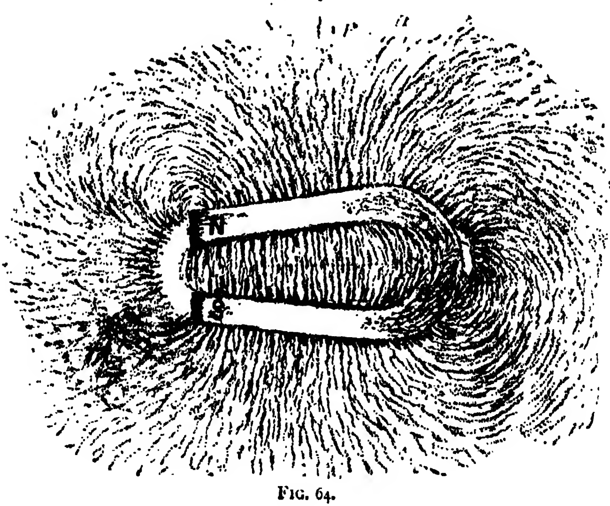

FIG. 64.

but when an iron keeper is placed across the poles of the magnet, the majority of the lines of force will leave the filings and take an easier and shorter path through the keeper. The majority of the filings beyond the keeper will therefore, on the cardboard being again tapped, cease to have any definite arrangement, excepting in the immediate vicinity of the poles, as illustrated in fig. 64.

2. How could you arrange a combination of magnets so that the earth should have no magnetic action on it? If you had such a combination would it be affected if an ordinary magnet were brought near to it? Give reasons.

2. If two magnets of equal length and equal strength were placed side by side with their similar poles pointing in opposite directions, the earth would have no magnetic effect upon the combination. The attraction between the north pole of the earth and the north-seeking pole of one magnet would be just balanced by the repulsion between that pole of the earth and the south-seeking pole of the other magnet. Similarly the south pole of the earth would attract the south-seeking pole of one magnet and repel the north-seeking pole of the other magnet equally. Such a compound magnet would therefore lie indifferently in any position. If, however, an ordinary magnet were brought near to the combination, repulsion or attraction might take place, due to the fact that one of the poles at the nearer end of the compound magnet might be appreciably nearer to the pole of the approaching magnet than would be the other pole at that end of the compound magnet. It should be remembered that the earth's poles are so far away that they are practically equidistant from all the poles of the compound magnet in any position.

3. A glass tube is nearly filled with steel filings and corked at both ends. It can then be magnetised by any of the ordinary methods, but loses its magnetic properties when shaken. Explain this.

3. When the tube of steel filings is magnetised, each filing which participates in the magnetisation is made a complete mag-

net, having its north- and south-seeking poles ; and as the filings are arranged so that all the north-seeking poles point in one direction, and all the south-seeking poles in the opposite direction, the whole tube of filings acts as a single magnet. When, however, the filings are subsequently shaken up, facilities are given for them to turn round and form little closed magnetic circuits, with the consequence that the magnetisation of the filings as a whole ceases, and no external evidence is afforded of magnetic polarity.

4. A long vertical iron bar is placed in the centre of a ship, so that the upper end is close to the compass on that side which is nearest to the bow of the ship. What effect would this have on the compass when the ship was sailing true east (i.) in the northern, (ii.) in the southern hemisphere?

4. When sailing in the northern hemisphere the iron bar would be magnetised by the earth, with a north-seeking pole at its lower end, and a south-seeking pole at its upper end. Supposing the ship, fig. 65, to be sailing true east, its course would be more or less at right angles with the magnetic meridian, and the upper end or the south-seeking pole of the iron bar A being close to the compass needle, it would deflect it to the east of the meridian, and would therefore appear to indicate that the ship is sailing in a north-easterly direction.

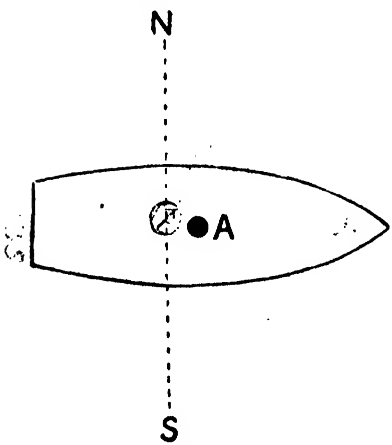

FIG. 65.

When the vessel is in the southern hemisphere a north-seeking pole would be developed at the upper end of the

bar, and consequently the north-seeking pole of the compass needle would be deflected to the west, and would therefore appear to indicate that the ship is travelling in a south-easterly direction.

FRICTIONAL ELECTRICITY

5. How would you prove that glass and silk when rubbed together are equally and oppositely charged?

5. The simplest way of proving this is to first thoroughly insulate the silk rubber from the hand by holding it in a sheet of indiarubber or by wearing an indiarubber glove. The silk and glass, having been electrified by friction, should then be placed together on the cap of an electroscope, and it will be noticed that no divergence of the leaves is produced. If, however, either the glass or the silk be removed, the remaining substance causes a divergence. That the two bodies are electrified is therefore proved; and the fact that no divergence results when both of them are present proves that they were equally and oppositely charged.

6. The cap of a gold-leaf electroscope resting on an insulating stool is joined by a wire to the gas pipes. How will the leaves be affected when a charged glass rod is brought near to the electroscope? Give reasons for your answer.

6. When the cap of an insulated electroscope is connected by a wire with the gas pipes, the cap and leaves are joined directly to earth and remain, under all conditions, at the earth's potential. When, therefore, a charged glass rod is brought near, the leaves are still at the earth's potential, and will not diverge unless the rod is placed near the side of the electroscope, so as to electrify the tinfoil strips which are usually gummed on the inside of the glass shade, but which, in this particular case, are insulated from the earth by means of the stool. In that case the glass rod would repel a positive charge to the

inner faces of the tinfoil strips, and this would electrify the leaves negatively by induction, and they would consequently diverge slightly.

7. A large Leyden jar, the outer coating of which is earth-connected, is charged; if you wish to discharge it with the electric tongs, which coating should you touch first with the tongs, and why?

7. The tongs should be placed in contact with the outer coating first, because that is at the same potential as the experimenter, viz. at the earth's potential, and there would then be no risk of a shock being received in the event of the tongs proving defective. If the tongs were first placed in contact with the knob, and thereby with the inner coating, the tongs would take up the higher potential of that coating, and there would then be some risk of a discharge taking place through the body of the experimenter and the earth, instead of directly between the two coatings through the tongs.

8. An uncharged brass ball is hung by a silk thread inside an ice-pail, which is insulated and positively charged. First the ball and then the pail is momentarily touched by a wire which is in contact with the ground, and the ball is then removed from the pail without touching it. Explain the series of electrical states which the pail assumes.

8. While the ball remains insulated, the pail retains its positive charge without any alteration in the distribution of the charge; but when the ball is momentarily earth-connected by means of the wire, the charge passes to the inside of the pail, and acting inductively upon the ball develops a negative charge there, repelling the equivalent positive through the wire to earth. If now the pail is in the same way momentarily earth-connected, no effect will be produced, because the negative charge remaining on the ball will prevent the positive on the pail escaping. If the ball be now removed, the positive charge will again distribute itself over the outer surface of the pail.

9. Two brass spheres, one of which is heated by a lamp, while the other is surrounded by melting ice, are connected

by a metal rod. If it is desired to make electricity pass from one to the other along the rod in the same direction as that in which the heat flows, describe the nature of the electrical arrangements which would correspond (i.) to the lamp, (ii.) to the ice.

9. The sphere which is heated by the lamp is kept at a higher temperature than that which is surrounded by melting ice, and which is therefore at the temperature usually considered as zero. Consequently heat will flow along the rod from the sphere at the higher to the sphere at the lower temperature. Similarly, if electricity is to pass along the conducting connecting rod, the end of the rod connected to the sphere which is at the higher temperature should be joined to or placed near the prime conductor of an electrical machine, while the other end should make contact with the earth. Under these circumstances the electrical machine would, while being worked, correspond to the lamp, as it would keep the end of the rod near it at a positive or higher potential than the other end making contact with the earth. The earth being at the zero potential would correspond to the ice.

VOLTAIC ELECTRICITY

10. What evidence have we that the difference of electrical condition between the positive and negative poles of a voltaic battery is the same as that between the prime conductor and the rubber of an electrical machine?

10. This question should be compared with question No. 10 of 1887, from the solution to which it will be seen that if the positive and negative poles respectively of a voltaic battery be connected to a pair of insulated metal plates, having a, say positively electrified gold leaf suspended midway between them the leaf will be attracted by the plate connected to the negative or zinc pole of the battery, while it will be repelled by the plate connected to the positive or copper pole of the battery. If

the same pair of plates be connected to the positive or prime conductor of an electrical machine, and to the negative conductor or rubber of the machine respectively, the leaf will be repelled by the former and attracted by the latter. It is thus shown that the prime conductor of an electrical machine corresponds to the positive pole of a battery, while the rubber of the machine corresponds to the negative pole of the battery.

Several other methods can be adopted; for example, it can be shown that a sewing needle placed inside a small coil of wire will be magnetised in the same manner when the positive pole of a battery and the prime conductor of an electrical machine are connected in turn to the same end of the coil, the other end of the coil being connected to the negative pole of the battery or the rubber of the machine, as the case may be.

11. Describe a galvanometer in its simplest form, and explain what additions you would make to it in order to increase its sensitiveness.

11. The simplest form of galvanometer consists of a horizontally suspended magnetic needle over or under which a wire carrying a current is made to pass, the wire being, in the absence of the current, parallel with the needle. The passage of the current causes a deflection of the needle, the direction of the deflection depending upon the direction of the current and upon the relative position, over or under, of the wire. The angle of deflection depends upon the strength of the current and the nearness of the wire to the needle. There are two ways of increasing the sensitiveness of such a galvanometer. One way is to wind the wire a number of times round the needle, the plane of the coil so formed being parallel to the axis or length of the needle. The other addition may be a second needle, the two needles being connected together by a piece of brass or other convenient rigid substance at a distance of about three-quarters of an inch, but with their dissimilar poles adjacent. The two needles should be as nearly equal in strength as possible, and under these circumstances they would form an astatic pair, and then the effort exerted by the earth's magnetism to make them point north and south, or along

the meridian, would be a minimum. Consequently a current-carrying wire stretched between them would endeavour to deflect both needles in the same direction, and a comparatively feeble current would suffice to produce a considerable deflection. The deflection could be increased by winding the wire several times round *one* of the needles, preferably the lower one, and we should then have an ordinary astatic galvanometer.

12. Explain why, when a sufficiently strong current passes through an incandescent lamp, the lamp becomes hot, while the wires which lead the current to it are comparatively cold.

12. The amount of heat developed in a conductor by a given current is directly proportional to the resistance of that conductor. Now the resistance of the fine carbon filament of an incandescent lamp is enormously greater than that of the copper wires leading to the lamp, length for length; consequently the heat developed in the former is considerably greater in amount than the latter. Moreover, there is considerably more material in a length of, say, five inches of wire than in a similar length of carbon filament, so that, even were the same quantity of heat developed in the two, the filament would be raised to a much higher temperature than would be the wire. Still greater must be the difference in temperature when the resistance of the smaller substance is so much higher; and this difference is quite sufficient to account for the fact that, while the filament of the lamp is made white-hot, the wires leading to the lamp remain comparatively cold.

13. An insulated wire is wrapped for a few turns in a right-handed coil round the core of a ring of soft iron, and then for a few turns in a left-handed coil round the core. What is the magnetic condition of the ring when a current is passed through the wire from the left-handed to the right-handed coil?

13. The diagram, fig. 66, illustrates the soft iron core over which wire has been wound in a right-handed coil, R, and a

left-handed coil, L. A reference to the solution to question No. 12 of 1885 will show that the current entering at the left-handed coil develops at the end where it enters a north-seeking pole, a south-seeking pole being developed at the end of the coil at which the current emerges. But in entering the coil R the current develops a south-seeking pole, so that the two coils conspire to develop a south-seeking pole S between them. The current on emerging from the coil R develops a north-seeking pole, so that both coils conspire to develop a north-seeking pole N on the left of the figure.

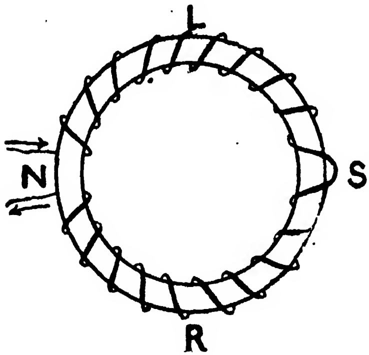

FIG. 66.

14. A horseshoe-shaped piece of copper is hung from the arm of a balance, so that the two legs dip into two different vessels containing a solution of copper sulphate, and weights are placed in the other pan till the balance is in equilibrium. An electric current is passed for some time through the vessels and the horseshoe, the electrodes being copper plates dipping into the liquid in the vessels, but not touching the horseshoe. When the current is stopped will the balance still be in equilibrium? Give reasons for your answer.

14. Let A, B, fig. 67, be the two vessels containing copper sulphate solution, and C D the horseshoe-shaped piece of copper suspended from the arm of a balance, and dipping into the solution contained in A and B. The current, on the completion of the circuit, passes from the copper pole of the battery G to the electrode E, and thence through the solution in A to the horseshoe, through which the current passes to the vessel B, leaving the latter by way of the electrode F. As the current passes through A, copper is dissolved off the plate E,

but an exactly equal quantity is deposited from the solution upon the leg C of the copper horseshoe. In a similar way the current in passing through B causes copper to be dissolved off the leg D of the horseshoe, and an equal amount to be deposited from the solution upon the electrode F. Now the strength of the current in the two vessels is the same; and as

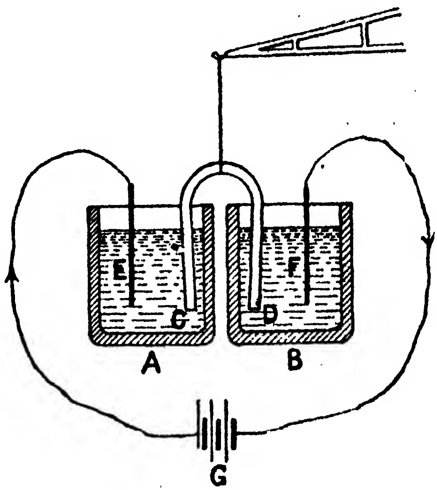

FIG. 67.

the amount of copper dissolved and deposited is directly proportional to the strength of the current, it follows that the leg C gains in weight exactly as much as the leg D loses, and the total weight of the copper horseshoe therefore remains constant. Under these circumstances the balance will remain in equilibrium.

1895

MAGNETISM

1. A compass needle is deflected by a bar magnet placed some distance away from it. How is the deflection modified (if at all), when a bar of soft iron is placed parallel to, but not touching, the magnet? Give reasons for your answer.

1. This problem is somewhat similar in character to No. 2 of 1887 and No. 4 of 1890, to which the student is referred. Many of the lines of force which in the absence of the iron bar (A B, fig. 68) extend from the magnet N S to the compass needle *n s*, and thereby cause the deflection, are diverted and made to pass through the easier path afforded when the iron bar approaches (after the manner illustrated in fig. 40). The deflection of the needle is therefore proportionately reduced from say the position *n s* to the position *n′ s′*. The fact that the iron bar A B is only near to, instead of touching the magnet N S, merely reduces the effect which would be observed were the two in contact. In the diagram we have

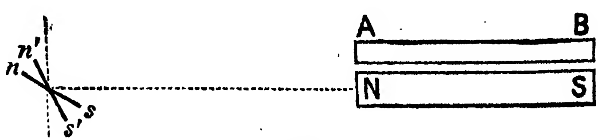

FIG. 68.

assumed that the original position of the needle was along the magnetic meridian, indicated by the vertical dotted line, and that the magnet and iron bar are placed on the east side of the

needle. Similar results would follow were the relative positions of the needle and magnet changed.

2. A vertical steel rod, of which a portion, the length of which is less than half the length of the rod, is stuck into the earth, is found to be rather strongly magnetised. If you were given a compass and a foot rule, how could you, without disturbing the rod, form an estimate of the length of the buried portion?

2. In solving this problem it is necessary to assume that the rod has been symmetrically magnetised; that is to say, that its so-called neutral line or zone is midway between its extremities. This line or zone could then be found approximately as the portion which would attract indifferently either pole of the compass needle. The determination could be confirmed by first ascertaining the polarity of say the upper end of the rod. Let us suppose that end to be the south pole. Then let the compass be placed say to the east of the upper end and gradually lowered. The needle will be most strongly deflected (with its north pole towards the rod) when opposite the south pole, and the deflection will gradually diminish until about the middle of the rod is reached. Next, let the compass be placed on the ground and to the south of the rod, and let it be gradually raised. The lower portion of the rod being of north polarity, the north pole of the needle will be repelled and the south pole attracted, and the deflection will gradually diminish until about the middle point of the rod is reached. The probability is that the two 'middles' will not coincide; but if the distance between the two points at which the needle pointed north and south be halved, a fairly close approximation to the true middle of the rod will have been determined, and it is only necessary to measure, by means of the foot rule, the distance between this middle and the upper end of the rod. Such distance being half the length of the rod, its full length can be estimated therefrom, and this length, minus the length above the ground, gives the length of the buried portion.

3. A bar of soft iron is held vertically over the centre of a dip needle, but not near enough to have magnetism induced in it by the needle. Is the dip increased or diminished by the presence of the bar, and would the result be the same in the two hemispheres?

3. The iron bar will become magnetised as a consequence of its being placed in the earth's magnetic field in such a position that some of the lines of that field will pass through it. In the northern hemisphere the lower end (A, fig. 69) of the bar will have north polarity induced in it, and as the dip needle will be inclined with its north pole downwards there will be attraction between the south pole of the needle and the lower end of the iron bar. Hence the dip will be increased. For similar reasons the lower end (A, fig. 70) will in the southern hemisphere have a south pole induced in it, while the dip needle will incline with its south pole downwards. There will therefore be attraction between the upper or north pole of the needle and the lower end of the iron bar. Hence the dip will again be increased, so that the effect upon the needle will be the same in both hemispheres.

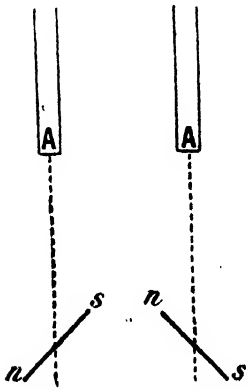

FIG. 69. FIG. 70.

4. A magnetised steel rod is placed at a considerable distance from a compass and produces a certain deviation of the needle. The rod is then broken in two, and one of the halves is placed in the same position as before. Will the deviation of the compass be less or greater than before? Give reasons for your answer.

4. The steel rod being at a considerable distance from the compass, the inductive effect of the rod upon the compass is negligible, and the only effect to be considered is the mutual effect of the magnetisations of the rod and the compass. When

two magnets are thus situated, the turning or deviating power of the magnet is proportional to what is called the 'moment' of the magnet. The moment of a magnet is the product of the strength of one of its two (equal) magnet poles, and the distance between those poles (that is to say, the length of the magnet). In other words, if M is the moment of the magnet, m the strength of one of its equal poles, and l its length, then

$$M = m \times l.$$

It therefore follows that if the steel rod is broken in halves one half will have a moment of $m \times \frac{1}{2} l$; that is to say, the moment of the half of the rod is half the moment of the whole rod Hence, when the rod is broken, the deviation due to one half of the rod is less than the deviation due to the whole rod.

In simpler language the problem may be solved by saying that repulsion by the similar pole always accompanies attraction by the dissimilar pole. It follows that with the shortened magnet the similar pole is nearer to the needle than was the case with the unbroken rod. For this reason the deviation is greater when the whole rod is employed than when only one half of it is used.

FRICTIONAL ELECTRICITY

5. Explain why the points on the prime conductor of an electrical machine are necessary; also why the rubbers are earth-connected.

5. The prime conductor is under induction by the approaching or charged portion of the revolving plate or cylinder; and this conductor has to be charged positively by the neutralisation of the negative on the portion nearest the plate. This portion obviously carries a charge opposite to that on the plate, or the charge on the plate being positive the charge on

the near portion of the prime conductor is negative. It is a well-recognised law that a discharge from a pointed conductor is much more rapid and takes place much more readily than from a rounded one, because the density of the charge at the points is comparatively considerable; and it follows that if the portion of the prime conductor near the plate is studded with points, the charge on that portion will speedily be neutralised, while the charge at the distant end will be left undisturbed. The potential of the prime conductor is determined by the excess of charge on the end remote from the plate over that on the end near the plate.

The rubbers are earth-connected in order to keep them at the earth's potential. Were this not done, the rubbers and the plate would speedily arrive at the highest possible potential difference, and then no further charge could be developed. In other words, the rubbers would, because of their small capacity, assume a negative potential, and the time would soon come when, if any further charge were developed, it would dissipate itself by discharging either on to the plate or on to the prime conductor itself. In either case the charge, which could be accumulated upon the prime conductor, would be comparatively very small.

6. A sheet of tinfoil is suspended by a dry silk thread and charged as highly as possible by an electrical machine, but on discharging it only a slight spark is obtained. If the tinfoil is placed on a sheet of dry glass lying on the table, a bright spark can be obtained after the tinfoil has been charged by the machine. Explain the cause of the difference.

6. The amount of electricity which can be accumulated upon a conductor is dependent upon its 'capacity,' and this capacity is dependent upon the proximity of neighbouring conductors. When the tinfoil is suspended there is no other conductor very near, and a small quantity of electricity suffices to raise its potential to the same potential as that of the machine itself. When, however, the tinfoil is placed on the sheet of

glass lying on the table, the thickness of the glass determines the distance of the other conductor (the wood of which the table is constructed is for this purpose a sufficiently good conductor). Then the charge communicated to the tinfoil acts inductively upon the earth-connected table, and develops an opposite charge thereupon. Consequently the potential of the tinfoil is lowered, and it is in a position to receive a further charge, and this goes on until ultimately the tinfoil attains a potential above that of the table corresponding to the potential difference between the machine and the table. Evidently the quantity of the charge upon the tinfoil will be much greater than when the tinfoil is suspended, and as the brightness of the spark is dependent upon the quantity of electricity involved in the discharge, it follows that the spark will be brighter when the tinfoil is near the earth-connected table than when it is suspended in the air remote from other conductors.

7. Describe an experiment to prove that two parts of the same conductor may be differently electrified although they are at the same potential.

7. Let A C be an insulated conductor placed in proximity to the charged prime conductor B of an electrical machine or other positively charged body. The near portion of A C will be negatively electrified and the remote portion positively. This can be proved by touching, say, the end C with a proof plane (consisting of a small disc of metal, such as a halfpenny, attached to one end of a stick of sealing wax or a thin rod of ebonite). The free end of the insulating handle should be held in the hand, and on the metal portion touching the cylindrical conductor a portion of the charge at C will pass on to the proof plane. If

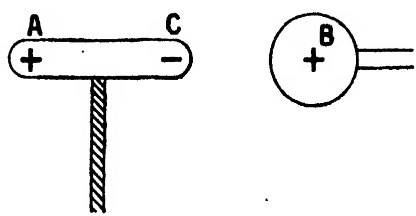

FIG. 71.

measure prevents the deposition of moisture, its surface is much less smooth than is the surface of glass, and it therefore to some extent allows dust to accumulate. Shellacked glass should therefore be rubbed down with a dry duster before being used. In cases where the glass cannot be coated with shellac, as for example in the case of a rod to be electrified by friction with silk, it is imperative that the glass should be made thoroughly hot in order to insure perfect dryness. So long as the glass is appreciably hotter than the air there is little risk of its condensing atmospheric moisture, and its properties as an insulator will therefore be retained.

9. How may it be experimentally proved that external electrified bodies produce no electrical force within a hollow conductor?

9. Let us first assume that the hollow conductor (A B, fig. 72) is insulated. The external body C, assuming it to be positively electrified, will cause the opposite portions of A B to take up positive and negative electrifications respectively; but, as shown in the solution to the seventh question of this year, the whole conductor will be at one common potential. Assuming, in the second place, that A B is uninsulated, either temporarily or permanently, then there will be only one charge on it, namely, the negative at B. In this case also the hollow conductor is at one common potential; that is to say, the potential of the earth. In both cases, therefore, the whole of the hollow conductor, both inside and outside, is at a common potential. In such circumstances the conductor D, held by means of a

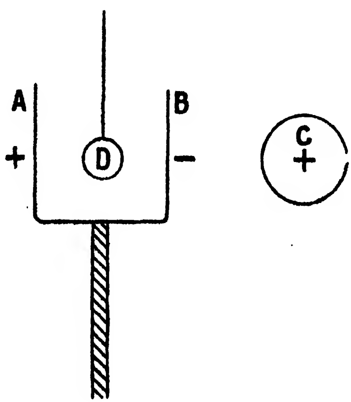

FIG. 72.

dry silk thread, will experience no electrical force; that is to say, it will neither be attracted nor repelled when placed inside A B. When first dropped inside, it will at once take up the potential of A B, which will be positive while A B is insulated, but will be zero when it is earth-connected. If the ball be lifted out and applied to an uncharged electroscope, there will be no divergence of the leaves, and this will also be true if the ball has been allowed to touch the bottom of the hollow conductor. It is, of course, understood that the conductor D is not touched by any external conductor while it is within A B.

VOLTAIC ELECTRICITY

10. Two galvanic cells are made of exactly the same materials, but in one cell the plates are much larger than in the other. What would be the effect of introducing both into a circuit so that they tend to send currents in opposite directions? Give reasons for your answer.

10. In order that a current might be developed in such a circuit, it would be necessary that one of the cells should develop a higher electromotive force than the other. But the two cells are of exactly the same materials, differing only in size, and have consequently the same electromotive force. Electromotive force is determined by the energy of the chemical reactions or changes, and is independent of the *amount* of such reactions or changes, that is to say, the electromotive force set up is unaffected by the size of the cell. For these reasons no current would flow through the circuit.

11. Two pieces of lead connected by wires with the poles of a voltaic battery, are dipped into a solution of lead acetate. State what happens, and show how to prove your statements experimentally.

11. The passage of the current would decompose the lead acetate. The acid portion would act upon the positive elec-

trode or the piece of lead by which the current enters the cell, and the amount of lead thus taken up would be exactly equal to the lead separated from the solution in the process of decomposition. In such circumstances the strength of the solution would remain unchanged. The lead separated from the acetate during the decomposition would be deposited upon the negative electrode in a pure metallic state, and in the form of fine feathery threads, which would gradually extend across the cell, and in time short-circuit it.

12. An electrical current passes upwards through a vertical wire. Explain the difference in the behaviour of a compass needle when it is placed (1) at a certain distance due magnetic north of the wire; (2) at the same distance due magnetic east of the wire.

12. Let A (fig. 73) represent the section of the wire passing vertically through the paper. The current travelling in an upward direction will set up a circular field of force about the wire, the direction of the lines of force composing the field being left-handed, as indicated by the arrow-heads. In such circumstances, the compass needle *n s*, placed due magnetic north of the wire, will strive, in its effort to coincide with the direction of the lines of force, to take up an east and west direction, with its north pole pointing westward, as indicated by n' s'. When

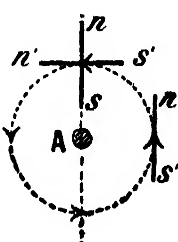

FIG. 73.

the compass is placed as shown at n'' s'', on the east of the wire, it will be already pointing as nearly as possible along the lines of force. It will suffer no deviation, but will rather be held in its position more powerfully than when the current ceases to flow.

13. Pieces of zinc and copper are thrust through a cork which floats in dilute sulphuric acid, and their upper ends are connected by a wire that is coiled round a straight horizontal glass tube resting on the cork.

Describe the behaviour of the apparatus (1) before, (2) after a small magnet of hard steel has been placed in the glass tube.

13. The pieces of zinc supported in dilute sulphuric acid constitute a simple cell, and will set up a current which will circulate around the coil; a north pole will consequently be developed at one end of the coil and a south pole at the other end. The direction of the polarity will depend upon the direction in which the wire is wound and upon the method of connection to the zinc and copper plates. If, however, the current be made to travel from the copper plate C round the coil in a right-handed direction, as shown in fig. 74, then the

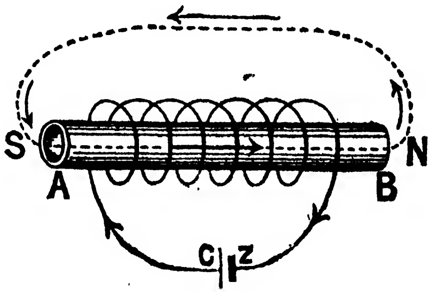

FIG. 74.

end A will become a south pole, the end B becoming north. The apparatus will therefore rotate until the coil lies north and south, with the end B pointing northwards. The effect of placing a small magnet in the glass tube will depend upon the way in which the magnet is inserted and upon its magnetic strength. If we suppose the field developed by the magnet to be stronger than the field due to the coil, then, when the magnet is inserted with its north pole at A and its south pole at B, the direction in which A B points will be reversed; that is to say, it will rotate through an angle of 180°. If, however, the needle is inserted with its north pole at B, then the coil will, more strongly than before, be impelled to point with the end B northwards. If the magnet is very weak, it may, when

inserted with its north pole towards A, either neutralise the tendency to point north and south, or may simply reduce that tendency.

14. Two magnets are firmly attached at right angles to a wire which is suspended so that the magnets can rotate in a horizontal direction. The magnets are parallel, and like poles are turned in the same direction. You are supplied with a flexible wire through which an electric current is passing, and are required to determine (without touching the magnets) whether they are of equal strengths. Describe and explain your procedure.

14. The disposition of the two magnets is shown in fig. 75. The wire should be placed parallel to the magnets and equidistant between them. They will then tend to set themselves at right angles with the wire, but turning in opposite directions. The magnets being firmly attached to the same piece of wire, it is obviously impossible for them to turn in opposite directions. If, therefore, the magnets are of the same strength, they will remain undisturbed; but if one of them be stronger than the other, then the stronger will proportionally overcome the weaker, and the combination will move in the direction which would be taken by the stronger needle if it alone were present.

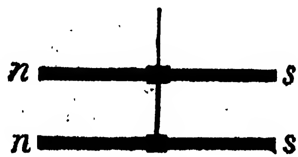

FIG. 75.

1896

MAGNETISM

1. A strip of steel is bent about the middle point, so that the two halves are inclined to each other at a right angle. It is then magnetised so that its extremities are south poles and the angular point a north pole, and is placed on a flat piece of cork floating in a basin of water. How will it set?

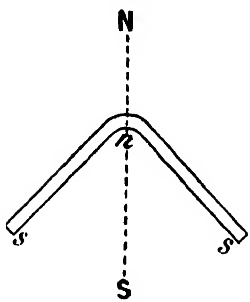

FIG. 76.

1 The strip of steel is magnetised as shown in fig. 76. The angular point being of north polarity will point northwards, and the two south poles being assumed to be of equal strength, the magnet will come to rest when the magnetic meridian N S bisects the angle, as shown in the figure.

2. A bar of soft iron lies on a table at right angles to the magnetic meridian, and a compass needle is placed at some distance from the bar with its centre on the axis of the bar produced. The end of the bar nearest to the needle being kept in the same position, the bar is then turned round, upon the table, until it is parallel to the magnetic meridian, the fixed end of the bar being to the south. Describe the behaviour of the compass (1) before, (2) during the rotation of the bar.

2. The solution of this problem depends to some extent upon whether the bar of soft iron is originally on the east or on the west of the compass needle. Let it be supposed that it is on the east. Then (fig. 77) the needle *n s* will remain in the magnetic meridian; that is to say, it will continue to point north and south so long as the bar of iron remains undisturbed, because the two poles of the needle are equidistant from the bar, and because the bar is uninfluenced by terrestrial magnetism. When, however, the bar is turned in the direction C N the earth's lines of force begin to pass through it lengthways, and it becomes more and more powerfully magnetised as it approaches the meridian. The end A of the bar being to the south will have south polarity induced in it, and consequently the north pole of the needle will be gradually deflected to the east, attaining its maximum deviation when the bar of iron lies north and south.

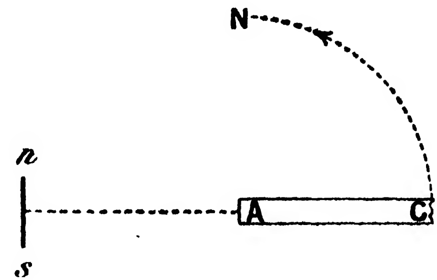

FIG. 77.

3. Iron filings are scattered on a piece of cardboard which is placed over a horseshoe magnet and tapped. What difference would be observed in the arrangement of the filings when the ends of the magnet were joined in turn by bars of (1) steel, (2) soft iron, and (3) copper?

3. Copper is a non-magnetic metal, and when a bar of that metal is placed across the poles of a horseshoe magnet it will be ineffective, and the filings will arrange themselves as though nothing other than air were there (see fig. 78). A bar of soft iron, however, allows the lines of force due to the magnet to pass through it freely, and the arrangement of the filings will be much less pronounced, especially in the vicinity of the magnet poles. The lines of force on the side of the

iron remote from the magnet will (see fig. 79) show a very different arrangement from that taken up when the iron is absent, and there are hardly any filings observable just above

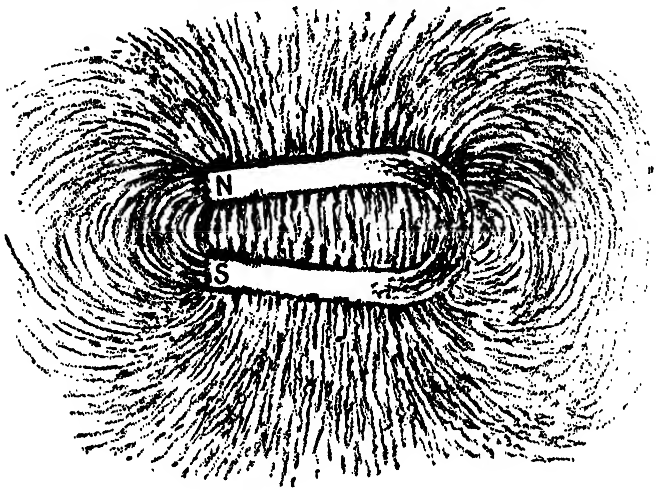

FIG. 78.

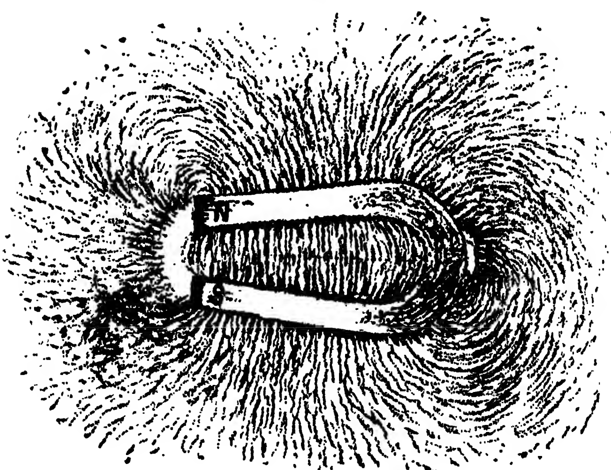

FIG. 79

the iron because the lines of force go through the iron and not through the air space on the surface of the cardboard. The effect of a piece of steel is similar in character to that of a piece of iron, but is much less pronounced because the lines of force do not pass through it so readily as through iron.

4. A compass is carried round the earth at the equator. Describe generally the direction of the deviation of the needle from due north at the different parts of the journey.

4. Starting, say, on the line of 'no variation' which passes through the middle of South America (about long. 56 W.) and where the needle points due north and south, it will turn to the west as it journeys eastward, until a maximum is attained. The westerly variation will then diminish until a line of no variation is again reached in the Indian Ocean, and almost due south of the Indian peninsula. Continuing its journey the needle will be deflected towards the east, the angle made with the geographical meridian gradually increasing until a point of maximum variation is attained. After this the angle will diminish until the original starting point is reached, when the needle will again point north and south.

FRICTIONAL ELECTRICITY

5. Describe how to arrange an experiment so that a conductor charged all over with negative electricity may nevertheless receive a further charge of negative electricity on being connected with the ground by a conducting wire.

5. Let B (fig. 80) be the conductor charged 'all over' with negative electricity. If it be earth-connected, after a body A charged positively to a higher degree than it itself is charged has been brought near it, a further negative charge will be induced in B. A greater effect may be produced if A is made of such a shape as to enable it to envelop B.

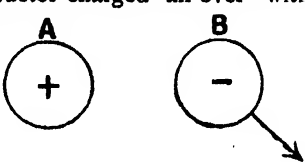

FIG. 80.

6. Two pairs of light pith balls are hung at the opposite ends of an insulated conductor, one pair being suspended by silk and the other by cotton threads. Describe and explain the behaviour of the balls if the conductor is gradually electrified more and more strongly.

6. The pith balls suspended by silk threads will remain unaffected, because the silk being an insulator none of the charge communicated to the insulated conductor will pass to the pith balls. The cotton thread is, however, a sufficiently good conductor to allow a portion of the charge to pass down to the pith balls suspended by the cotton. Being similarly charged, they will be mutually repellent, and will therefore stand out from one another. The amount of electricity passing into these balls will increase as the electrification of the insulated conductor is increased, and consequently there will be a corresponding increase in the divergence of the pair of pith balls.

7. A flexible conducting thread, to the end of which a needle is attached, lies at the bottom of an insulated charged iron pail. One end of the thread always remains in contact with the pail, while the needle is lifted out of the pail (without touching it) by a silk thread. Describe and explain any change which takes place in the charge in the pail during the process.

7. We will assume it to be the examiner's intention that it is the needle which is to remain untouched during the experiment. On this basis nothing will happen until the needle rises near to the top of the pail, because up to that level the needle will be in the condition of a conductor wholly inside a charged hollow conductor, and we know that in such circumstances the contained conductor is without charge. As it rises above the pail, however, the needle becomes a sharp-pointed conductor electrically connected with the charged pail. The needle will therefore gradually but rapidly discharge the pail, which will in consequence cease to be an electrified conductor.

8. The top of an electroscope is coated with sealing wax, which is rubbed by flannel held in an insulating support. Describe and explain the behaviour of the leaves (1) while the rubbing is in progress; (2) when the flannel is removed.

8. The friction between the flannel and sealing wax will cause them both to be electrified, the flannel positively and the sealing-wax negatively. The two charges will, however, be equal, and so long as the flannel remains in position the two charges will neutralise each other, and there will consequently be no effect upon the leaves of the electroscope. When, however, the flannel is removed, the negative charge upon the sealing wax will act inductively upon the electroscope, the cap or top of which will be electrified positively and the leaves negatively. The leaves will therefore diverge the one from the other.

9. A Leyden jar standing on an insulating stool is electrified by a machine, while its outer coating is touched by the knob of an exactly similar Leyden jar of which the outer coating is held in the hand. The first jar is then disconnected from the machine, is taken in the hand by the outer coating, and is presented with its knob to that of the second jar. Does a spark pass? Give reason for your answer.

9. Some care must be exercised in performing this experiment, otherwise an inconvenient shock may be the result. The two jars being exactly similar would have the same capacity. The knob of the first jar (the one charged directly by the machine) would have a certain potential given it by the machine. The outer coating of the second jar held in the hand would be at the earth's potential. The outer coating of the first jar and the knob of the second jar would, as they are in contact, be at a common potential, the value of which would be just midway between the earth's potential and the potential of the knob of the first jar; and the difference of potential between the two coatings of one jar would therefore be the same as the potential difference between the two coatings of

cumstances the leaf will be positively electrified so long as any charge remains in the jar, and it will be found that if A be connected to the zinc or negative terminal, D, of the battery, and B to the copper or positive terminal E of the battery, the positively electrified gold leaf will be attracted towards A. If A be removed, the leaf will be repelled by B. If A be replaced and B removed, attraction will result. This demonstrates that the plates A and B differ from each other, and that they are respectively negatively and positively electrified. But these plates are electrically connected to the two terminals of the battery, and as no current is flowing they are at the same potentials as the terminals to which they are respectively connected. Hence the potential at D is negative, and at E positive. If now the battery be removed and the prime conductor of an electrical machine be connected to B, and the rubber be insulated and connected to A, it will be found that the positively electrified gold leaf will be attracted by A and repelled by B, thus showing that the electrical condition of the prime conductor is similar to that of the copper or positive pole of the battery, and that the electrical condition of the rubber is similar to that of the zinc or negative pole of the battery.

If the rubber of the machine be earthed in the usual way, it will of course assume the earth's potential, as will also the plate A. The difference of potential, however, between A and B will be unaffected, and the effect upon the gold leaf will be the same. To complete the analogy it will be necessary to 'earth' the zinc pole of the battery (and the plate A), but here again the *difference* of potential is unaffected, and likewise the result of the experiment.

It will probably be found expedient when the experiments are performed with the electrical machine to place the plates A and B a greater distance apart than when experimenting with the battery, in consequence of the much greater potential difference set up by the machine.

11. When a current passes along the wire joining the terminals of a battery, does the current also pass through the battery? Give reasons for your answer.

11. The current which passes along the wire also passes through the battery. The battery forms part of the circuit, and the current must therefore pass through it. A more or less liquid electrolyte is always essential in the cell between the plates; and this electrolyte, which must also be a chemically compound substance, always undergoes chemical change. This change is directly proportional to the strength of the current, and to its duration, and is of precisely the same character as would result were a similar electrolyte placed in a vessel external to the battery, and having immersed in the liquid a pair of electrodes of the same materials as the plates of the battery. The passage of the current through such a vessel can alone be responsible for the change which is brought about; and as similar and equal changes take place in every cell of which the battery is composed, the changes there effected must result from a similar cause. As a matter of fact, the external vessel having plates and liquid similar to the battery constitutes an additional battery cell, and therefore increases the electromotive force proportionally. If, however, we suppose the battery to consist of 'simple' cells, containing zinc and copper plates immersed in a weak solution of sulphuric acid, and if we place a portion of the same solution in the external vessel and use two electrodes of the same metal - say copper - similar, but not the same, changes will take place. In the simple cells sulphate of zinc and hydrogen gas will be formed, while in the external cell we shall get sulphate of copper and hydrogen. In this case the external cell will not cause an increase in the electromotive force; but the chemical change which takes place is due to the current, and proves that the same current must pass through the battery. That such a current does pass can be seen by placing the battery north and south, and leading the wires away from it, say, round the walls of the room. If a suspended magnetic needle be placed either over or under the battery, the needle will be deflected either to the east or to the west, according to the direction of the current.

12. Describe and explain the construction of an astatic galvanometer and the cause of its sensitiveness.

12. Two magnetic needles of equal length, and as nearly as possible of equal magnetic strength, are fixed parallel to each other by means of a piece of brass wire, or other rigid substance, and with their opposite poles pointing in the same direction, as shown in fig. 82. This combination is suspended by means of a piece of unspun silk or other torsionless fibre. Two similar flat coils of insulated copper wire are placed close to and on opposite sides of the lower needle, n_1, s_1. The coils are wound on frames or

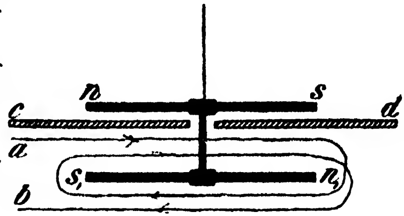

FIG. 82.

'formers,' so shaped that the needle can move freely in and out of them. Immediately under the upper needle is fixed a piece of cardboard or other non-magnetic material, with a circular scale printed or engraved upon its upper surface, a diametrical slot being cut in it so as to allow the pair of needles to be lowered into or raised away from the coils. The dial is so fixed that when the needles are at rest one end of the upper needle is pointing to the zero of the scale, and the plane of the pair of needles is parallel to the planes of the two coils. When a current is passed through the coils the needles are deflected, and the amount of the deflection is dependent upon the strength of the current. The galvanometer is very sensitive for two reasons, viz. (1) the very weak directive force exerted by terrestrial magnetism; and (2) the fact that the current passing along the sections of the wire between the horizontal planes of the two needles tends to make those needles point in the same direction. If the two needles were absolutely equal in all respects the pair would be absolutely astatic; that is to say, the combination would come to rest in any position without any directive force due to terrestrial magnetism. However much care may be taken, one is sure to be a little larger or a little more highly magnetised than the other, and

the combination is consequently directed with a force proportional to the difference between the two needles. This force is always less than if only one of the needles be used; and as the force tending to bring the combination into the meridian is feeble, so also is the force required to deflect it from the meridian. This, then, is the chief reason why the astatic galvanometer is sensitive. The second reason mentioned above is explained by the fact that the current which we will assume to enter at *a* passes under the upper needle from north to south, and over the lower needle from south to north. The north pole of the upper needle and the south pole of the lower needle are therefore both deflected from the plane of the paper towards the reader; that is to say, they move together. The consequence is that with a given current strength the deflection produced by the two needles is greater than that which would result from the use of either one of them alone.

Of course the current passing through the sections of the wire below the lower needle tends to move the two needles in opposite directions; but as the upper needle is comparatively far away, the effect upon that needle is small and altogether insufficient to neutralise the effect exerted upon the lower needle.

13. A long straight wire is stretched on a table in the direction of the magnetic meridian, and a dip circle, with its plane parallel to the magnetic meridian, is placed on the table near to the wire and on the west side of it. Will the dip of the needle be altered when an electric current is passed along the wire from south to north, and if so, how? Give reasons.

13. The wire is placed to the east of the needle, which on the passage of the current will tend to set itself at right angles with the wire in its effort to so set itself as to coincide with the lines of force developed by the current. The current travelling from south to north will strive to make the needle point vertically with its north pole upwards, and consequently the dip of the needle will be diminished. If the current be strong

enough the needle will set itself with its north pole uppermost, as in that position the needle will most nearly coincide with the direction of the lines of force set up by the current.

14. Insulated copper wire is wound on a thin brass rod from end to end in such a way as to form a long spiral, and the ends of the rod are bent round until they touch each other. If an electric current is passed round the wire, what will be the effect on a compass needle placed close to the spiral? Would the effect be different if the rod were of iron instead of brass? Give reasons for your answer.

14. If the ring of brass be placed in a horizontal plane, and on a level with the needle, the compass needle will tend to set itself tangentially to the ring in consequence of the fact that the turns of wire will be more or less vertical, and the lines of force set up by the current in the neighbourhood of the needle will be in a horizontal plane. The needle will of course strive to set itself along these lines of force, and the nearest approach to such a position is obtained when the needle sets itself at right angles with the straight line joining the centre of the needle and the centre of the brass ring.

When an iron rod is substituted for the brass rod, practically the whole of the lines of force set up by the current would circulate in the iron rod, and consequently the compass needle would be practically unaffected by that current, although it is probable that the needle would be deflected by the iron itself as a consequence of its magnetic properties.

1897

MAGNETISM

1. A bar magnet has consequent poles at its middle point. Describe its effect on the direction of a freely suspended magnetic needle which is moved from one end of the bar magnet to the other at a constant small distance above it. The effect of the earth's magnetism on the needle may be neglected.

1. We will suppose the bar to be magnetised with south polarity at its extremities and the north pole or poles at its middle point, as illustrated in fig. 83. When the needle is

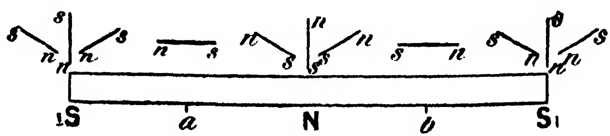

Fig. 83.

suspended over one end, say s, of the bar, its north pole will dip toward the south pole of the bar. The dip will diminish until the point *a* approximately midway between s and N is reached, when it will lie horizontally because the dipping tendencies of its two poles are equal. On passing the point *a* the south pole will begin to dip, and the dip will increase until the middle of the needle arrives almost immediately over N. On passing N the needle will turn round with its north pole *n* pointing towards S_1, the south pole of the needle continuing to dip towards N. This dip will diminish until it arrives over the point *b* midway between N and S_1, when it will again lie

horizontally, and for the same reason as in the position over the point *a*. Beyond *b* the north pole of the needle will dip, and this dip will gradually increase, attaining a maximum when the needle is directly over s_1.

2. Two equally magnetised bar magnets, each six inches long, lie on the table, parallel to each other, four inches apart. The poles which are nearest to each other are of opposite kinds, and the lines which join them are perpendicular to the magnets. Draw a picture showing the directions of the lines of force between the magnets. How will a rod of soft iron six inches long be affected when placed parallel to and halfway between the magnets? Neglect the effect of the earth's magnetism.

2. The direction of the lines of force, as delineated by iron

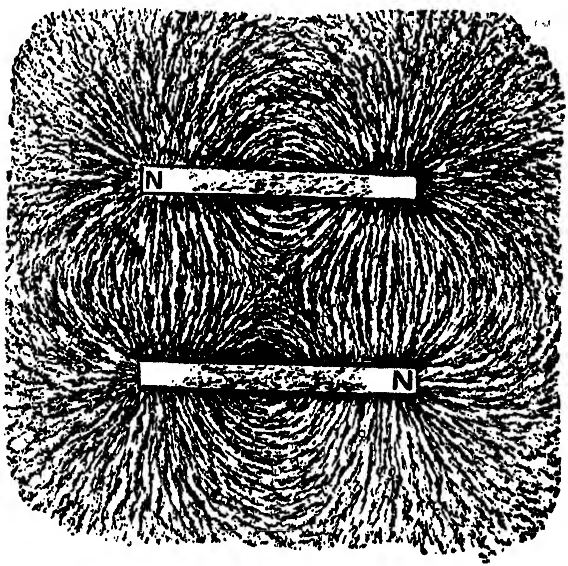

Fig. 84.

filings sprinkled on a sheet of paper or glass placed over the magnets, is shown in fig. 84.

When a soft iron rod is placed between the magnets many of the lines of force will pass through the iron, the number so passing being the same from the two magnets. As, however, owing to the arrangement of the magnets, the two sets of lines of force pass through the iron in opposite directions, no definite polarity will be developed, the north polarity at one end due to one magnet being equal to the south polarity at the same end and due to the other magnet. An illustration

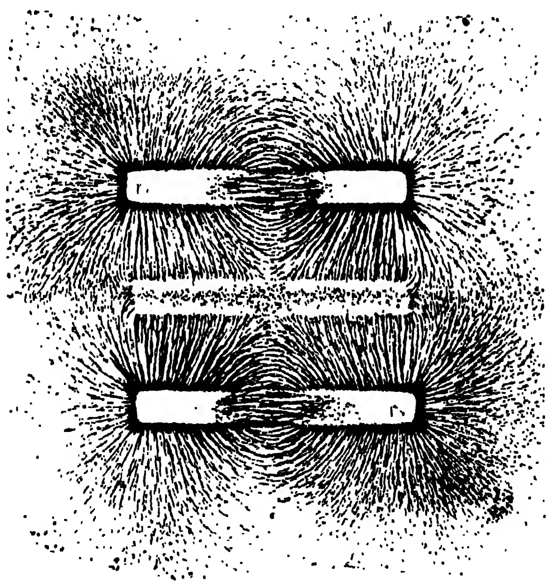

FIG. 85.

of the arrangement taken up by the iron filings is given in fig. 85.

3. If you were required to magnetise a circular ring of steel so that it should show no signs of magnetisation, how would you proceed? and how, being allowed to deal with the steel in any way that you pleased, would you prove that it was really magnetised?

3. A bar magnet should be fixed horizontally on a table with one pole, say the north, at or a little over the edge. The ring should be held by the fingers in a vertical plane, and in such a position that the axis of the bar magnet produced should pass along a diameter of the ring. The experimenter should start a foot or two from the magnet, and, twisting the ring round in its own plane, gradually approach the magnet. When the ring arrives near to the magnet pole the revolution should be continued for some little time and at a uniform rate, the number of revolutions depending upon the strength of the magnet and the dimensions of the ring. Without once stopping the revolutions the experimenter should now recede from the magnet until he gets fairly out of its field. It will then be found that the ring possesses no apparent polarity, because all the magnetised particles are pointing with their north poles in the same direction round the ring. If, however, the ring be cut through at any point, the two ends will be found to possess equal and opposite polarity.

Another method would be to wind a helix of wire round the steel and send a current through it. The current would set up lines of force which would pass round the steel ring without extending into the neighbouring air space. Such a ring would give no evidence of magnetisation unless it were cut through, when the two poles would show themselves.

4. If the magnetic state of the earth were due to a large magnet placed inside the earth, of which the axis and middle point coincided with the axis and centre of the earth respectively, how would (1) the declination needle and (2) the dipping needle behave at different points on the earth's surface, and in what respects would this behaviour differ from that which is actually observed?

4. A magnet so placed would point to the geographical instead of to the magnetic poles, and the geographical and magnetic poles of the earth would therefore be coincident. Moreover, if the magnetic state of the earth is to be considered as solely determined by the magnet, the effect of the various

masses of iron included in the different parts of the earth would have to be neglected. In such case the earth's magnetic field would be absolutely symmetrical, and as a consequence there would be none of those irregular distributions of magnetic force which are at present evidence of the general want of symmetry in the earth's field as manifested by the deflections of the declination and dipping needles. Assuming, then, this symmetrical field to exist, a declination needle would at all parts of the earth's surface point along the geographical meridians; that is to say, there would be no declination anywhere. The dipping needle would lie horizontally at all parts of the geographical equator, and the angle of dip at all points on any one parallel of latitude would be the same. At present the lines of equal declination are, instead of describing circles round the earth, more or less sinuous, and make in most places an angle with the geographical meridian; and similarly the lines of equal dip are not circular, but make at the various points on the earth's surface an angle with the parallel of latitude.

FRICTIONAL ELECTRICITY

5. A rod of sealing wax and a piece of flannel after having been rubbed together are insulated and placed some distance apart. How do their potentials differ from each other and from the potential of the earth? How would you prove the truth of your answer?

5. In answering this, a great deal depends upon the moment at which the flannel is to be insulated. If the flannel is held in the hand during the rubbing, and retained there after the electrified sealing wax is removed, the flannel being earth-connected through the hand will be at the earth's potential. If, however, the sealing wax is not removed until the flannel has been insulated, then the flannel will be at a positive or higher potential than the earth, while the sealing wax will be at a negative or lower potential than the earth.

If the flannel and the sealing wax after having been rubbed

be placed together on the cap of an uncharged electroscope no effect will be produced ; hence, if there is any electrification at all, the two bodies must be equally and oppositely charged. On removing either, say the sealing wax (being careful at the same time not to earth-connect the flannel), the leaves of the electroscope will diverge, and if a positively electrified body be brought near, the divergence will increase, proving the flannel to have been at a positive potential. If the sealing wax be brought near a negatively electrified electroscope an increased divergence will result, proving the sealing wax to be at a negative potential.

6. Two parallel insulated metal plates, A and B, are placed a small distance apart, and one of them (A) is charged with positive electricity. Draw a picture showing the lines of electric force between and around them. *How will the lines be altered when B is earth-connected ?

6. The presence of the second plate B will make very little difference in the arrangement of the lines of electric force due to the charge on A so long as B is insulated. The arrangement is illustrated in fig. 86. When, however, B is

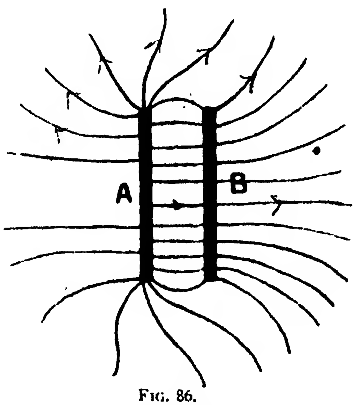

FIG. 86.

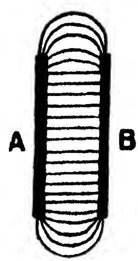

FIG 87.

earth-connected, the majority of the lines of electric force will be concentrated upon the space separating the two plates, as shown in fig. 87.

7. Explain the circumstances under which it is possible for a spark to pass between two conductors charged with the same kind of electricity.

7. A spark will pass between two conductors charged with the same kind of electricity' if the potential of one of them be higher than that of the other. Suppose, for example, that we have two insulated spheres of the same size, both positively electrified, but one of them having twice the charge which the other has. Then the more highly charged sphere will have twice the potential of the other, and on being brought into proximity a spark will pass from the one to the other in the effort to bring the two spheres to a common potential.

8. Describe an experiment by which you would illustrate the fact that the potential is the same at every point of an electrified conductor upon which the electricity is at rest.

8. This can be proved by joining a long piece of wire to the cap of an electroscope, and attaching the other end to the disc of a proof plane (see answer to question No. 7, 1895). If the proof plane be held by its insulating handle and the disc be applied to any part of the electrified conductor, a certain divergence of the leaves of the electroscope will result; but on applying the disc to other parts of the conductor no difference in divergence will take place, clearly proving that all parts of the conductor are at a common potential.

9. Describe the construction of the Leyden jar, and give reasons based (1) on experiment and (2) on theory for believing that it can be used to store up a relatively large charge of electricity.

9. A Leyden jar consists of a glass jar or bottle with a wide neck. The glass should be thin, hard, and dense, and free from lead. The inner and outer surfaces are coated up to within two or three inches of the shoulder with tinfoil, which can easily be made to adhere by means of a little ordinary gum. The neck of the jar should be fitted with a stopper of wood or other suitable material, and a metal rod should

be passed through the middle of the stopper. To the lower end of the rod should be fixed a piece of light chain sufficiently long to reach the bottom of the jar and to remain in contact with the tinfoil when the jar is tilted. The upper end of the rod should terminate in a metal ball. The surface of the glass which is not coated with tinfoil should be treated with a layer of thin shellac varnish, in order to prevent the condensation of atmospheric moisture and to effectually insulate the two metal coatings from each other, or rather to insulate the outer coating from the stopper, for this stopper, which is usually of wood, is a fair conductor, and is electrically connected with the inner tinfoil coating by means of the metal rod and chain.

Such a jar can be used for storing up a relatively large charge. Let the jar, after having been warmed so as to dispose of any moisture, be placed on an insulating stool with its knob near the prime conductor of an electrical machine. On turning the machine a few small sparks will be seen to pass between the prime conductor and the jar, after which no further charge will pass to the jar. If the two coatings of the jar be then connected a small spark will pass, and the jar will be discharged or neutralised. Let the knob of the jar be again placed near the machine, but let the outer coating of the jar be earth-connected. The machine will now be able to pour a long stream of small sparks into the jar, but in this case also a time will arrive when no more will pass. If the jar be now discharged by placing one end of a piece of wire in contact with the outer coating, and bringing the other end near the knob, a comparatively long and brilliant spark will result, the effect of which is to discharge the jar.

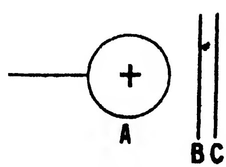

FIG. 88.

If we suppose B, C, fig. 88, to represent the two metallic coatings of the Leyden jar, and A the prime conductor of the electrical machine, which is brought near to the plate B, electricity will accumulate on B until its potential is nearly equal

to that of A. As, however, the surface of B is very limited, its capacity will be very small, the presence of C having very little effect so long as it remains insulated. In these circumstances the quantity of electricity stored in the Leyden jar is very small. When, however, the outer coating represented by the plate C is earth-connected, the effect is equivalent to making the plate C a part of the earth; that is to say, to increase its capacity infinitely. The result is that the capacity of the condenser is very largely increased, and as a consequence the potential due to the charge communicated while C was insulated is considerably lowered; B is therefore in a condition to receive a further charge from A, and it will continue to do so until the potential of B is again nearly equal to that of A. If the jar is not discharged instantaneously the charge will be gradually dissipated, the duration of the charge depending upon the insulating properties of the jar and the humidity of the atmosphere.

VOLTAIC ELECTRICITY

10. Describe the chemical action that takes place in a Daniell cell when its terminals are connected by a wire.

10. It is usually stated that surrounding the zinc plate in a Daniell cell there is a quantity of dilute sulphuric acid. As a matter of fact, in practical work no sulphuric acid whatever is used, but a weak solution of zinc sulphate is either placed in the zinc division or is allowed to form itself in the cell before it is joined up for use. We will therefore consider the liquids employed as weak zinc sulphate solution in the neighbourhood of the zinc plate, and a saturated solution of copper sulphate in the copper division. When the terminals are connected by a wire and a current of electricity is generated, the zinc sulphate attacks the zinc plate and gradually dissolves it. The zinc particles which thus enter into the solution displace an equal quantity of zinc particles from the solution. These displaced particles enter into chemical action with the copper

sulphate and displace the copper. If the copper sulphate be limited in quantity the solution is gradually transformed into zinc sulphate solution, and in that case metallic zinc would be deposited upon the copper plate, and the surfaces of the two plates being then alike no electromotive force would be set up and the current would cease to flow. The practice is, however, to place in the copper division a quantity of copper sulphate crystals, which dissolve as rapidly as the already dissolved molecules are decomposed by the liberated zinc. In these circumstances there is for every particle or atom of zinc dissolved from the zinc plate one atom of pure copper deposited from the copper sulphate solution upon the copper plate. The one plate is therefore constantly becoming lighter, while the other is as constantly becoming heavier. The copper deposited is of a crystalline character and very brittle. By bending the copper plate the deposited copper can easily be detached, and it then breaks up like a biscuit. The chemical changes are represented by the formulæ—

$$\underset{\text{Zinc}}{Zn} + \underset{\text{Zinc sulphate}}{ZnSO_4} + \underset{\text{Copper sulphate}}{CuSO_4} = \underset{\text{Zinc sulphate}}{ZnSO_4} + \underset{\text{Zinc sulphate}}{ZnSO_4} + \underset{\text{Copper.}}{Cu.}$$

11. How would you show that the difference of the potentials of the terminals of a battery increases with the number of cells arranged in series, supposing that you were not allowed to join the terminals by a wire so as to produce a current?

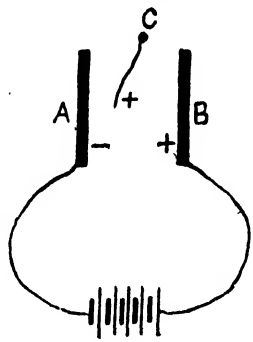

FIG. 89.

11. The terminals of the battery, which it is assumed consists of a large number of cells, should be joined to a pair of metal plates, A, B (fig. 89). These two plates will take up the same potentials as the terminals of the battery to which they are respectively connected, the plate connected to the zinc terminal becoming negative and that connected to the copper (or carbon or platinum) terminal

becoming positive. From C is suspended a gold leaf, connected to the knob of a charged Leyden jar, but otherwise insulated. This leaf will therefore be kept at a fairly uniform positive potential, and will in consequence be attracted by A and repelled by B. If the number of cells be increased, the deflection of the leaf will increase, or the plates may be moved farther apart and the same deflection obtained. In either case it is shown that when the number of cells varies there is a corresponding variation in the potential difference set up.

12. A rod of carbon, thick at one end and tapering towards the other end, is connected by copper wires with the poles of a battery. If the battery is powerful, what appearance will the carbon present? Give reasons for your answer.

12. Carbon offers a very much greater resistance than copper or any other of the metals, and therefore, as resistance varies inversely as the cross section of a body, the resistance of the thinner end of the carbon rod will be higher than the resistance of any other portion of the circuit, and as the work done or the energy expended upon the various parts of a circuit is proportional to the resistance of those parts, it follows that the work done upon the tapered end of the carbon will be greater than in any other portion of the circuit. When work is done or energy is expended upon a circuit in this way, heat is developed, the amount of heat being directly proportional to the amount of work or energy. As a consequence the temperature of the thin end of the rod will rise considerably, and if the current is sufficiently strong it will become luminous, that is to say red or even white hot. The increase of temperature of the carbon would gradually fall from the thin end to the thick end, so that if the thin end be, say, white hot or thereabouts, the luminosity will gradually pass through yellow and red heat until at the thick end there is no luminosity; that is to say, the carbon is still black, although it may be hot enough to ignite a match when the head is placed against it.

13. If you wished to produce a magnetic field which should be as uniform as possible, but of which you could vary the strength at pleasure, what arrangements would you make?

13. A uniform magnetic field is one in which the magnetic lines of force are straight, parallel, and equidistant. Such a field may be obtained in a variety of ways, but the most satisfactory is perhaps that which results from making a long helical coil and sending a current through it. Well inside the coil the field will be uniform, and the strength of the field or the density of the lines of force composing it is simply proportional to the strength of the current which generates it. By the density of the field is meant the number of lines of force which thread through it, or more correctly speaking, the density of the field of force is proportional to the number of lines of force per unit area of cross section of the field.

14. Describe the construction of the most sensitive galvanometer with which you are acquainted.

14. There are many sensitive galvanometers available, but the one which is most likely to be placed in the elementary student's hands is that known as the astatic galvanometer.

Two magnetic needles of equal length, and as nearly as possible of equal magnetic strength, are fixed parallel to each other by means of a piece of brass wire, or other rigid substance, and with their opposite poles pointing in the same direction, as shown in fig. 90. This combination is suspended by means of a piece of unspun silk or other torsionless fibre.

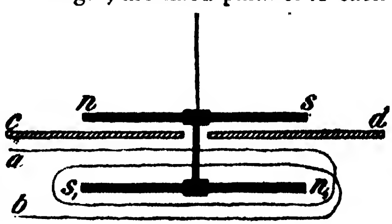

Fig. 90.

Two similar flat coils of insulated copper wire are placed close to and on opposite sides of the lower needle, n_1, s_1. The coils are wound on frames or 'formers,' so shaped that the needle can move freely in and out of them. Imme-

diately under the upper needle is fixed a piece of cardboard or other non-magnetic material, with a circular scale printed or engraved upon its upper surface, a diametrical slot being cut in it so as to allow the pair of needles to be lowered into or raised away from the coils. The dial is so fixed that when the needles are at rest one end of the upper needle is pointing to the zero of the scale, and the plane of the pair of needles is parallel to the planes of the two coils. When a current is passed through the coils the needles are deflected, and the amount of the deflection is dependent upon the strength of the current. The galvanometer is very sensitive for two reasons, viz. (1) the very weak directive force exerted by terrestrial magnetism, and (2) the fact that the current passing along the sections of the wire between the horizontal planes of the two needles tends to make those needles point in the same direction. If the two needles were absolutely equal in all respects the pair would be absolutely astatic; that is to say, the combination would come to rest in any position without any directive force due to terrestrial magnetism. But it is impossible to make them exactly equal. However much care may be taken, one is sure to be a little larger or a little more highly magnetised than the other, and the combination is consequently directed with a force proportional to the difference between the two needles. This force is always less than if only one of the needles be used; and as the force tending to bring the combination into the meridian is feeble, so also is the force required to deflect it from the meridian. This, then, is one reason why the astatic galvanometer is sensitive. The second reason mentioned above is explained by the fact that the current which we will assume to enter at *a* passes under the upper needle from north to south, and over the lower needle from south to north. The north pole of the upper needle and the south pole of the lower needle are therefore both deflected from the plane of the paper towards the reader; that is to say, they move together. The consequence is that with a given current strength the deflection produced by the two needles is greater than that which would result from the use of either one of them alone.

Of course the current passing through the sections of the wire below the lower needle tends to move the two needles in opposite directions ; but as the upper needle is comparatively far away, the effect upon that needle is small and altogether insufficient to neutralise the effect exerted upon the lower needle.

circumstances, such as the strength of the magnet, the length and weight of the iron rod, and the flexibility or facility for twisting manifested by the string.

2. A piece of soft iron and a piece of hard steel of the same size and shape are separately rubbed from end to end by the north pole of a strong bar magnet. How will you test their magnetic condition, and what difference will you find between them?

2. The magnetic conditions of the iron and steel bars would best be tested by bringing them in succession towards one of the poles of a horizontally suspended magnetic needle. It would be found that either end of the iron bar would attract the needle, but that one end of the steel bar would attract the needle and that the other end would repel it. This clearly proves that the iron rod has no retentivity, and is not therefore a magnet; but the steel bar has retentivity, and in consequence thereof the bar becomes a magnet, the end of the bar last touched by the original strong bar magnet becoming a south pole. This end would repel the north pole of the suspended magnetic needle, and either end of the steel bar would if placed in iron filings raise some of them on being lifted out. Neither end of the iron bar would be capable of lifting the iron filings.

3. You are given three equally long and equally strong magnets. How would you arrange them so as to form an astatic system?

3. The three magnets should be placed in the form of an equilateral triangle with their opposite poles adjacent. The lines of force of the three magnets would then pass round the triangle, and the system would consequently come to rest if suspended on a piece of cork floating in water in any position. The combination would be in such circumstances astatic, but the ends of the bars should be chamfered so that no free corners should be exposed at the ends of the bars.

4. A steel bar suspended by a thread lies horizontally and points indifferently in any direction; but when it is

broken into halves, each half is found to point N. and S. when separately suspended like the whole bar. Explain the magnetic condition of the whole bar.

4. The whole bar is evidently a magnet with consequent poles, having, say, a north pole at the centre and south poles at the extremities. If such a bar be suspended horizontally it will point indifferently in any direction, because the directive effect upon one end is neutralised by the effect upon the other end. If, however, such a bar be broken in halves, each of the two parts will be perfect magnets, and consequently will point north and south.

FRICTIONAL ELECTRICITY

5. How would you show that a brass rod is capable of being electrified? Explain why on rubbing a brass rod and a glass rod the latter only ordinarily appears to be electrified by the friction.

5. To show that a brass rod is capable of being electrified, it is necessary to insulate the rod from the hand, otherwise the electric charge will be dissipated as fast as it is generated. The insulation is easily effected by holding the rod in a sheet of india-rubber. The rod on being beaten by a piece of fur or flannel will then be capable of showing that it is electrified. The difference between the brass and glass rods held in the hand and rubbed in the ordinary manner is explained from the fact that brass is a good conductor, while glass is an insulator. With the brass the charge is dissipated, but with the glass the charge is retained on the surface because it cannot escape. The latter remains, therefore, electrified, while the former becomes unelectrified as fast as it is electrified.

6. Into an insulated uncharged metal jar standing on the cap of an electroscope an electrified brass ball is lowered without contact; the jar is then touched for a moment with the finger, and the ball is next allowed to touch the jar, after which it is removed. Explain the various effects produced on the gold leaves.

6. When the brass ball electrified, say, positively is lowered into the jar, the ball acts inductively upon the jar, charging its inner surface negatively, and repelling the equal positive charge to the outside, the major portion of this charge being repelled to the leaves of the electroscope, as those leaves are electrically connected with the metal jar. The leaves therefore diverge with the positive charge. On touching the jar, the jar and electroscope are earth-connected and reduced to the earth's potential; that is to say, the leaves are discharged and consequently collapse. The negative charge on the inner surface of the jar remains unaffected; and as the electrified ball is wholly within a hollow conductor, the negative charge on the jar is exactly equal to the positive charge on the ball. Consequently, when the ball touches the jar, both the jar and the ball are neutralised and the leaves remain unaffected. Obviously this state of affairs is not altered by the removal of the discharged ball.

7. Two similar vertical insulated plates, A and B, are placed parallel to each other and about an inch apart. Each is connected to the cap of a separate gold leaf electroscope. State and explain the indications of the electroscopes when (1) a positive charge is given to A, and afterwards (2) B is touched.

7. On the positive charge being given to the plate A, a portion, depending upon the amount of the charge and the area of the plates, will pass into the leaves of the electroscope, which will then diverge with a positive charge. The remainder of the charge communicated to A will act inductively on B, charging the nearer surface thereof negatively. A corresponding positive charge will be repelled into the electroscope connected with B, and the leaves thereof will consequently diverge with a positive charge.

When B is touched, it and the electroscope connected with it are brought to the earth's potential; that is to say, the electroscope is neutralised or discharged and the leaves collapse. But the effect of touching B is to increase the capacity of the

pair of plates which are acting as a condenser, or, in other words, each plate will require a greater charge in order to maintain the potential difference between them. The positive charge in the electroscope connected with A will therefore pass up into the plate and leave the electroscope more or less completely discharged, so that the leaves of this electroscope will also collapse, or nearly so. The greater positive charge on A will at the same time induce a correspondingly greater negative charge on B; but as B is for the time being earth-connected, the leaves of the electroscope joined to it remain unaffected.

8. What is the evidence for the opinion that lightning is an electric discharge?

8. A lightning discharge is like an ordinary electric discharge in character, in that it is capable of magnetising steel rods, igniting explosive substances, deflagrating metallic bodies, and destroying life by 'shock.'

9. A sharp point is attached to the interior of a hollow metallic sphere. Describe and explain the action of the point (1) when the sphere is electrified; (2) when one end of a brass rod, the other end of which is held in the hand, is cautiously introduced into the sphere through a small hole so as not to touch the sphere, and is brought near to the point.

9. Assuming the point P (fig. 91) to be well inside the hollow metallic sphere, the point would have no effect upon the sphere when it is electrified, because the whole of the interior of a hollow electrified sphere is at a common potential, and there can therefore be no transference of electricity from the sphere to the point. When, however, the brass rod B, which is earth-connected by means of the hand, is introduced, the state of affairs is altered, because the rod is at the earth's potential. In such circumstances there is a difference of potential between the sphere and the rod, and as a consequence the charge on the

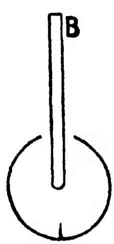

FIG. 91.

sphere will be rapidly dissipated by way of the point, until the whole sphere is brought to the earth's potential.

VOLTAIC ELECTRICITY

10. The terminal wires of an insulated battery consisting of a large number of cells touch the caps of two electroscopes. What are the effects upon the two sets of leaves, and what would be the further effects of touching one of the caps with the finger?

10. When the terminal wires touch the caps of the two electroscopes they will take up the negative and positive potentials of the battery, and the leaves of both electroscopes will diverge, as shown in fig. 92, the electroscope A connected with the zinc pole of the battery being negatively electrified, the electroscope B connected with copper, carbon, or platinum pole of the battery being positively electrified. When one of the electroscopes, say A, is touched, it and the end of the battery connected with it will take up the earth's potential, but the potential difference of the battery itself will remain unaltered; consequently the leaves of the electroscope A will collapse, but the leaves of the other electroscope B will increase in their divergence.

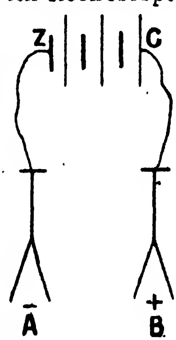

FIG. 92.

11. A straight horizontal wire is placed near and parallel to a compass needle and in the same horizontal plane with it. If a current is then passed through the wire, what effect is produced on the needle, and what occurs if the wire is (1) slightly raised, (2) slightly lowered?

11. Assuming the needle to be incapable of 'dipping,' there would be no effect upon it so long as the current is in the same horizontal plane as the needle. The tendency is to make the needle set itself at right angles with the wire, and

this could only be done by the needle dipping and assuming a more or less vertical position.

When the wire carrying the current is slightly raised, the needle is deflected in a horizontal plane and takes up a position more or less at right angles with the wire. If the current passes in a south to north direction, the north pole of the needle will be deflected to the westward.

When the wire is slightly lowered, the needle is again deflected and made to take up a more or less east and west position; but in this case if the direction of the current in the wire is from south to north, the north pole of the needle will turn to the eastward.

12. A glass cell is divided into two compartments by a porous partition. One compartment contains a strong solution of copper sulphate, the other dilute sulphuric acid. A copper plate and a zinc plate, which dip into these respectively, are joined to the terminals of a galvanometer, the needle of which is deflected, State and explain how the deflection will be altered if the copper sulphate is replaced by dilute sulphuric acid.

12. In the first case, the cell is to all intents and purposes a Daniell cell, free from polarisation The substitution of dilute sulphuric acid for the copper sulphate converts the cell into an ordinary single fluid 'simple' cell. The electromotive force developed by zinc and copper immersed in dilute sulphuric acid is lower than the electromotive force of a Daniell cell, and consequently the deflection of the galvanometer needle will be reduced when the acid solution is substituted for the copper sulphate. The removal of the sulphate also results in the evolution of a quantity of free hydrogen gas, some of which accumulates on the surface of the copper plate. This hydrogen reduces the area of the plate in contact with the solution, and therefore increases the resistance of the cell. Further, hydrogen being an electropositive element, its accumulation on the surface of the copper plate has the effect of gradually raising its potential in relation to the immersed zinc

plate. The comparatively weak current which is produced when the dilute sulphuric acid replaces the copper sulphate is gradually enfeebled, and the already smaller deflection of the galvanometer is gradually reduced in consequence.

13. Explain the meaning of the statement that the electric current flows in a circuit. By what experiments would you illustrate its accuracy?

13. In answering this question, it must not be forgotten that, in the first place, there is no such thing as an electric current; and, in the second place, nothing 'flows' in the circuit. The two ideas, that electricity is a current and that it flows, are simply conventional assumptions which are known to have no basis in fact, but which are nevertheless employed because they offer certain conveniences which cannot at present be obtained in any other way. It is, however, certain that something does take place in every part of a circuit through which a so-called current is assumed to flow, for if a compass needle be placed over or under any part of the circuit in any position other than an east and west position, the needle will be deflected. If the circuit be broken at any point, the effect upon the needle ceases forthwith. If we assume the rupture in the circuit to have been obtained by cutting a piece of wire forming part of the circuit, it would be necessary to bring the ends together again in order to affect the compass needle. The ends might for electrical purposes be brought together by means of another piece of wire, or by immersing them in a vessel of water or other conducting liquid. Such liquid, unless it be mercury, which is, chemically speaking, an elementary substance, will undergo decomposition as a result of the absorption of the electric energy, and the result will be the same, both in kind and in amount, if the liquid be introduced in any other part of the circuit.

14. Two galvanic cells are made by dipping (1) plates of zinc and platinum into a beaker of dilute sulphuric acid, and (2) plates of zinc and copper into another beaker containing the same liquid. The plates can be connected

by copper wires. Explain with diagram how the two cells may be connected in series so as to (1) strengthen, (2) weaken, the current produced by one of them.

14. The electromotive force set up by zinc and platinum plates immersed in dilute sulphuric acid is greater than when zinc and copper plates are used. Hence the zinc-platinum combination will, alone, produce a stronger current than will the zinc-copper combination.

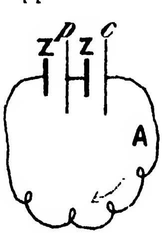

FIG. 93.

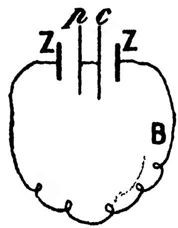

FIG. 94.

If the two cells be joined in series so that their respective electromotive forces are acting in the same direction round the circuit, as shown in fig. 93 (where P represents the platinum, C the copper, and Z the zinc plates), the current produced by the stronger cell, Z P, will be increased by the addition of the weaker cell, Z C. But if the platinum of the one cell be joined to the copper of the other, as shown in fig. 94, the electromotive force of the zinc-copper cell will oppose the electromotive force of the zinc-platinum cell, and will proportionally weaken the current produced by that cell.

1899

MAGNETISM

1. A straight steel watch-spring is magnetised, and is then bent so that its ends are in contact. What effect would it have on a compass needle to which it was brought near? and how would this effect be modified by the spring being cut into two parts while the original ends were still held in contact?

1. If the contact of the ends N S (fig. 95) were sufficiently good, the lines of force would pass wholly through the steel, and there would therefore be no effect on the compass needle. If, however, the spring be cut, say, at the point A, the original ends being still held in contact, two fresh magnetic poles would be developed at *n* and *s*, and the north pole of the compass needle would be repelled by *n*, and its south pole by *s*. It is immaterial where the spring is cut, for in every case the end nearest to the original north pole becomes a south pole, and the end nearest the original south pole becomes a north pole, so that if in the case shown in the figure the two portions of the ring were separated, there would be two perfect magnets.

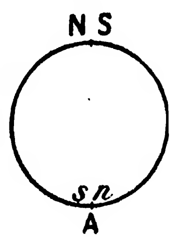

FIG. 95.

2. A magnet can rotate in a vertical plane about a horizontal line which lies in the magnetic meridian and joins the centre of the magnet to the centre of a compass needle. Describe the movement of the compass needle as the magnet slowly rotates.

2. The magnet is assumed to rotate in a plane at right

angles with the magnetic meridian. If we assume the magnet to start from a vertical position, the relative positions of the needle and magnet are as represented in fig. 96, where we have placed the magnet N S to the south of the needle. It might, of course, have been placed to the north, but the principle involved is the same in both cases. The compass needle can only move in a horizontal plane, so that it is unable to set itself parallel with the magnet, all that it can do being limited to a slight dipping when the magnet is in a vertical position. Let us assume that we are facing the side of the magnet remote from the needle, and that the magnet is rotating in a right-handed direction. As it approaches the horizontal position, its N pole will lie toward the east, and the compass needle will be deflected with its *s* pole pointing eastward; after the N pole of the magnet has passed the horizonal position, the deviation of the needle will diminish until when the magnet is again vertical (but with its N pole downward) the needle will be again unaffected by the magnet, and will point along the meridian. As the rotation of the magnet is continued, the N pole gradually rises on the west side, and the needle is again induced to take an east and west position, but this time with its *s* pole pointing westward. The closest approximation to parallelism will be obtained when the magnet N S lies horizontally. As the magnet continues its rotation, the deflection of the magnet diminishes, until when the magnet returns to the original vertical position the needle is again unaffected, and points along the meridian.

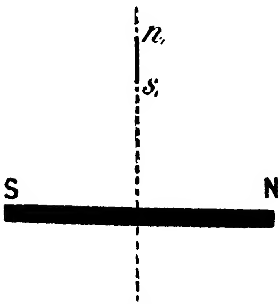

FIG. 96.

3. When a rod of soft iron, a yard long, is held in a vertical position, each end when held downwards attracts one pole of a compass needle and repels the other; but when the rod is held horizontally and in a certain direc-

tion, both ends attract both poles of the needle. Explain these facts.

3. The iron rod being *soft*, it is magnetised when in the vertical position by the lines of force due to terrestrial magnetism, its lower end being magnetised with north polarity; hence, whichever end of the rod is downward will repel the north pole and attract the south pole of the compass needle. When, however, the rod is held horizontally, more particularly if it lie in an east and west position, the earth's lines of force will not pass lengthways through it, and it will remain simply as a magnetic substance without any trace of magnetisation. In such circumstances either end of the soft iron rod will attract either pole of the needle.

4. What is meant by the magnetic inclination at any place? How would you show that it differs at different places?

4. Magnetic inclination is the angle which a magnetic needle, mounted so that it can rotate freely in a vertical plane, makes with the horizontal plane passing through its centre. It will make such an angle at all places which are not equidistant from the north and south terrestrial magnetic poles, because of its tendency to point direct towards the nearer magnetic pole of the earth. Those points on the earth's surface where the needle would be equally affected by the earth's poles, and where it would therefore take up a horizontal position, are said to be on the magnetic equator. To show that the declination differs in different places, it is only necessary to take the needle to places differently situated with respect to the magnetic poles of the earth, such as Edinburgh, London, and Paris, and note the differences in the angles which the vertically suspended needle makes with the horizontal plane at those places.

FRICTIONAL ELECTRICITY

5. State clearly the evidence for the opinion that there are two kinds of electrification.

5. The evidence is mainly experimental. Place an unelectrified smooth glass rod in a wire or other stirrup suspended by a thread (the conductivity of which is immaterial). Rub another smooth glass rod with silk, likewise an ebonite rod with flannel, and bring these electrified rods in turn near the suspended rod; attraction follows in both cases. This proves both rubbed rods to be electrified. Now electify the suspended rod by removing it from the stirrup and rubbing it with silk. Let this rod be again suspended, and bring the other previously electrified rods in turn near it. It will be observed that the electrified ebonite attracts the electrified glass, but that the suspended rod is repelled by the other rod of electrified glass. As opposite results are the outcome of opposite causes, it is clear that the electrification of the ebonite rod differs from that of the glass rod which was held in the hand; and as the two similar glass rods were rubbed with the same piece of silk, we may fairly assume them to be similarly electrified, while the flannel-rubbed ebonite is differently or oppositely electrified. Hence there are two kinds of electrification, and the law is deduced that bodies similarly electrified are mutually repellent, while bodies dissimilarly electrified are mutually attractive.

These deductions can be confirmed by providing a second rod of ebonite, and, after rubbing it with flannel, suspending it in the stirrup. Electrified glass will be found to attract the ebonite, while the other electrified ebonite will repel it. There are several other experiments of a kindred nature, all of which point the same way.

6. An insulated electrified ball is brought near the knob of an electroscope, which is then momentarily touched so that the leaves hang vertically. Explain why the leaves diverge when the ball is now moved either nearer to, or farther from, the knob.

6. When the ball is brought near the electroscope the latter is inductively electrified, and if the ball is positively electrified the leaves will also be positively electrified, the knob being negatively electrified. When the knob is momentarily touched, the electroscope is made to assume the earth's potential, and the positive charge in the leaves is neutralised or dissipated. When the positively electrified ball is brought nearer to the knob, the potential of the electroscope is raised; that is to say, a further inductive effect is exerted, the negative electrification of the knob being increased, and a proportional positive electrification being set up in the leaves. This latter charge causes the leaves to diverge. As the ball is withdrawn to its previous position, the previous state of affairs is resumed; that is to say, the potential of the electroscope is reduced, and the positive electrification of the leaves is neutralised by the corresponding portion of the negative electrification of the knob. When the ball is removed still further from the knob, the potential of the electroscope falls below zero; that is to say, the negative electrification of the knob is again reduced, and the negative thus released passes in part into the leaves, which therefore repel one another, but this time with a negative instead of a positive charge.

[If the knob were now touched by the hand, this negative in the leaves would be neutralised, and the electroscope *raised* to the earth's potential.]

7. The inner coating of a Leyden jar is charged by an electrical machine. Explain the difference (if any) in the result according as the outer coating is (1) insulated, (2) uninsulated, during this process.

7. The difference in the results will be considerable. When the outer coating of the jar is insulated, a comparatively small charge communicated to the inner coating suffices to raise the potential of the outer coating to nearly the same value as the inner coating; that is to say, the positive charge communicated by the machine to the inner coating speedily induces a sufficient charge on the outside to cause a quantity of positive

electricity to be liberated sufficient to raise its potential to about the same as the potential of the knob of the prime conductor. When that takes place no further charge can pass to the inner coating, and no further charge can be developed by the machine. When, however, the outer coating is uninsulated (or earth-connected), that outer coating becomes to all intents and purposes a part of the earth, and no charge which the machine can develop can under such circumstances affect the potential of the outer coating. If, therefore, the insulation between the two coatings of the jar were infinitely thin, the charge which could be communicated to the inner coating would also be infinite. As a matter of fact, however, a point is ultimately reached beyond which any charge communicated to the inner coating is either dissipated into the air or passes over the surface of the glass to the outer coating. But in any case the quantity of electricity communicated is considerably greater than when the outer coating of the jar is insulated. It therefore follows that the amount of electricity involved in the discharge of the uninsulated jar is much greater than with the insulated jar, and the spark is correspondingly thicker.

8. Two equal conducting spheres are charged, one with positive and the other with an equal quantity of negative electricity, and are placed a certain distance apart. A third conducting sphere, which is insulated but uncharged, is placed exactly halfway between them. What is (1) the state of electrification, (2) the potential, of this last sphere? Give reasons for your answer.

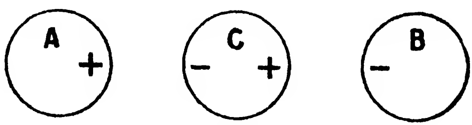

FIG. 97.
(The spheres are exactly equal and equidistant.)

8. The state of affairs is illustrated in fig. 97, where A represents the positively electrified sphere, B the negatively electrified sphere, and C the insulated but uncharged sphere

which is placed midway between them. C will be electrified, as shown in the figure; that is to say, the side nearest to A and farthest from B will be electrified negatively by induction, and the side nearest to B and farthest from A will be positively electrified. The two charged spheres conspire therefore to bring about the same result, and the two charges induced on C are equal. But the potential of A is assumed to be a certain amount *above* the potential of the earth, while that of B is exactly the same amount *below* it. The centre of C is exactly equidistant from A and B, and therefore the potential there, due to the one is exactly equal and opposite to that due to the other; that is to say, the potential of C is zero. This can easily be proved: if the finger be brought near it no spark will pass; and if it be connected by a wire with an electroscope, there will be no divergence of the leaves.

9. A charged glass rod is almost entirely discharged when a fine sewing needle held in the fingers is moved up and down the rod, the point of the needle not quite touching the rod. Explain this, and state whether the result would be the same if the needle instead of being held in the fingers were attached to a rod of sealing wax.

9. The glass rod is positively electrified, and the needle being held in the hand is earth-connected. Consequently the charge on the glass acts inductively upon the needle, and the needle being earth-connected, has infinite capacity, so that the negative charge accumulated on the point of the needle is comparatively great; that is to say, the density of the charge, or the amount of electricity accumulated upon the surface of the needle's point, is much greater than the density upon the rod or the amount of electricity accumulated upon a portion of the surface of the rod equal to the surface at the pointed end of the needle. In fact the density of the charge upon the needle is so great that it passes off by convection, whence it follows that the charge on the needle point will speedily neutralise the charge upon the opposite surface of the rod. As the needle is moved along the rod, the latter is therefore

completely neutralised. The phenomenon is known as the discharging effect of points; but obviously a great deal depends upon the sharpness of the point, and it is not at all difficult to notice the difference in the effect of the point of a needle as compared with the effect of the relatively blunt point of a pin. If the needle were attached to a rod of sealing wax, its capacity would be very small indeed, the sealing wax being an insulator, consequently the needle would be able to neutralise only a very small portion of the charge upon the rod. After that had been done the needle would be at the same potential as the glass, and no further induction or neutralisation would take place.

VOLTAIC ELECTRICITY

10. State whether local action or polarisation take place in (1) a Daniell cell, (2) a Leclanché cell, giving reasons for your statements.

10. Polarisation takes place in a Leclanché cell used continuously upon a circuit of low resistance because the hydrogen liberated from the ammonium chloride (or sal ammoniac) is set free faster than the carbon dioxide (or black oxide of manganese) can be decomposed. The hydrogen therefore accumulates and polarisation ensues. The great advantage of the Leclanché cell is that it is not liable to local action; that is to say, there is no chemical action going on unless the cell is developing a current, and a Leclanché cell may be kept idle for a considerable period of time without deterioration. This fact is probably due to the presence of an alkali and the absence of an acid in the solution.

In the Daniell cell there is no polarisation so long as the sulphate of copper solution is maintained, because any hydrogen which may be liberated is immediately taken up by the copper sulphate, and pure copper is then deposited upon the negative or copper plate. On the other hand, the Daniell cell suffers considerably from local action, as owing to the presence

of an acid or an acid salt in the zinc division the zinc plate is continuously being dissolved and the copper sulphate decomposed.

11. Two batteries, A and B, are made up of cells of the same kind arranged in series, A being composed of 60 and B of 30 cells. If the plates of a condensing electroscope are touched successively by the terminals of the two batteries and are then separated, will the divergence of the leaves depend upon whether the order in which the two points of contact are made is A, B or B, A? Give reasons for your answer.

11. The divergence will be much smaller in the one case than in the other. Assuming that each cell has an electromotive force of one volt, the electromotive force of the battery A is 60 volts, and of the battery B 30 volts.

If the terminals of the battery A be applied to the electroscope a potential difference of 60 volts will set up on the plates. If now the terminals of battery B be applied (the terminals of battery A having been removed), electricity will pass from the electroscope through the battery, because the electromotive force of the battery is lower than the potential difference of the plates, and these plates will therefore be reduced to 30 volts potential difference, or the same as that at the terminals of the battery B. On the separation of the plates a certain divergence of the leaves will take place. If the plates be replaced and discharged, and the battery B be applied, a potential difference of 30 volts will be set up. On the application of the terminals of battery A the potential difference will be raised to 60 volts, or the same value as the electromotive force of the battery. On removing the battery connections and separating the plates a fresh divergence of the leaves will ensue, but this divergence will be larger than the previous one, because the potential has been doubled. It will thus be seen that the potential difference is determined solely by the electromotive force of the battery last used.

12. Part of a wire is coiled round the bulb of a mercurial thermometer and another part round an iron rod. How are the thermometer and iron rod affected when a current is passed through the wire? And how are the effects altered (if at all) by reversing the direction of the current?

12. The current on passing through the wire will, if it be sufficiently strong, raise the temperature of the wire appreciably; some of this heat will be communicated to the thermometer and cause the mercury to expand and give a higher reading. The effect of the current on the portion of the wire coiled round the iron rod will be to magnetise the rod, the polarity of which will depend upon the direction of the current, the magnetisation itself depending upon the strength of the current. When the direction of the current in the wire is reversed there is no alteration in the effect upon the mercury, but in the case of the iron rod the magnetisation will be reversed; that is to say, the end which in the first case was of south polarity will now take up north polarity, and *vice versâ*.

13. Two galvanic cells consist respectively of (1) plates of zinc and copper, and (2) plates of zinc and platinum, dipped in dilute sulphuric acid of the same strength in each case. If the two zinc plates are joined by a wire, describe what occurs when the platinum and copper plates are also connected by a wire.

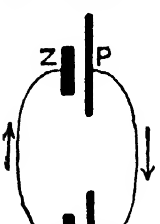

FIG. 98.

13. The two cells would be joined up as shown in fig. 98, where Z, C represent the zinc and copper plates in the one cell, and Z, P the zinc and platinum plates in the other cell. The electromotive force set up by zinc and platinum in dilute sulphuric acid is greater than that due to zinc and copper in the same solution, consequently a current will be set up in the direction indicated by the arrows.

14. A wire through which a current may be passed is stretched horizontally in a certain direction immediately over the centre of a compass needle. When a weak current flows the needle is not affected, but if the current be sufficiently increased the needle swings round and its north end points south instead of north. Explain this, and state in what direction the wire is stretched.

14. The needle, in the absence of any counteracting force, is held in the meridian by terrestrial magnetism. When another magnetic field is set up in the neighbourhood of the needle, the needle strives to take up a position where the two fields of force, that due to the earth and the one just established, shall be in equilibrium. In the case in question, however, the two are exactly opposite to each other in direction, and there is therefore no point or position to which the needle could be urged where it would be in equilibrium. So long, therefore, as the current was insufficiently strong to overcome the earth's field the needle would remain in the meridian. On the current being sufficiently increased, the effect of the earth's field is overcome, and an opposing field established strong enough to cause the needle to turn right round and point with its north pole to the south. In order to effect this the wire must be stretched at right angles with the meridian, so that the current can pass over the needle from east to west.

A SERIES OF ORIGINAL QUESTIONS.

MAGNETISM.

1. Why are the keepers of permanent magnets made of soft iron?

2. Give a diagram showing the arrangement of iron filings sprinkled over a sheet of paper covering a horseshoe magnet lying on the table, with its keeper a little distance away.

3. Give diagrams showing the arrangement of iron filings sprinkled on a sheet of paper placed over (1) a bar magnet with a piece of iron of the same length as the magnet placed parallel with and at a short distance from it; (2) with the same piece of iron placed in the same straight line as the magnet, and in contact with its north pole.

4. A square sheet of iron is placed on a table, and the south pole of a bar magnet is placed near one of its corners. How will the sheet be magnetised?

5. It is found that less force is required to remove a piece of steel from the poles of a horseshoe magnet than to remove a piece of soft iron of the same dimensions from the poles of the same magnet. Why is this?

6. A knitting needle is found to have a north-seeking pole at each end and a south-seeking pole in the middle. It is then broken at the middle; also midway between the middle and each end. Give a diagram showing the ultimate magnetic condition of each part.

7. A bar magnet placed at a certain distance from a compass needle causes a certain deflection. The interposition of a small iron disc with its plane at right angles to the line joining the magnet and the needle causes little difference in the deflection, but a large disc similarly placed causes the needle to return to its normal position. How do you account for this?

8. A compass needle when placed near a bar magnet is caused to oscillate, and these oscillations continue for a considerable time. Why? And what would you notice with respect to the time occupied by the oscillations, first at the commencement, and secondly when the needle has come almost to rest?

9. Why is it preferable to speak of the end of a magnetic needle which points towards the north terrestrial pole as the north-seeking pole rather than as the north pole of the needle?

10. It is said when a magnetic needle under the influence of terrestrial magnetism alone comes to rest, that no force is then being exerted upon it in a horizontal direction. How would you demonstrate this?

11. How would you account for the irregularity of the imaginary lines connecting together those places on the earth's surface where the magnetic declination is the same?

12. The north-seeking pole of a freely suspended magnet points to the north pole of the earth. How would you harmonise this with the law that similar magnetic poles are mutually repellent?

13. What is the magnetic axis of a magnet? Give diagrams showing the axes for a bar magnet and a horseshoe magnet respectively.

14. A long powerful bar magnet is laid on the table with its north-seeking pole pointing northwards, and a compass needle suspended by a silk fibre is held immediately over its centre. The needle is gradually raised to a considerable distance. How will the needle point when near the magnet, and how will it behave as it recedes from it?

15. A circular iron disc is supported in a horizontal plane on the end of a bar magnet placed vertically. Supposing the south pole to be uppermost, what is the magnetic condition of the disc? Give a diagram showing the arrangement of iron filings sprinkled on a sheet of glass placed over the disc.

16. Give diagrams showing the arrangement assumed by iron filings when sprinkled on a sheet of paper placed over a pair of bar magnets lying on the table and parallel to each other (1) with their similar poles pointing in the same direction, and (2) with their similar poles pointing in opposite directions.

17. A long needle after being magnetised is found to have a certain magnetic strength. It is then broken into two equal pieces. Will each piece be equal in strength to the unbroken needle? If not, why not?

18. Why is a magnet made of the horseshoe form when it is desired to exert the greatest possible force upon a piece of iron placed at a short distance from it?

19. What do you understand by the term 'magnetic meridian'?

20. Distinguish between an angle of declination and an angle of inclination.

21. Is the angle of dip greater or less at Aberdeen than in London? Give a reason for your answer.

22. Supposing a dipping needle to be carried round the earth along the 'line of no variation,' how would it be affected in the various parts of the journey?

23. A dipping needle comes to rest in the magnetic meridian, and a horizontally suspended needle is then placed a few inches to the south of it. How will the needles affect each other?

24. What difficulty would you anticipate in determining the centre of gravity of a strongly magnetised steel bar? How would you surmount the difficulty?

25. If one of the needles of an almost astatic pair be replaced by a copper wire of equal length and weight, will the remaining needle and copper wire oscillate more rapidly or less rapidly than did the pair of needles when moved from the position of rest? Give the reason.

26. A compass needle which lies in a perfectly horizontal position in London does not do so when taken to Capetown. How do you account for this, and how would you remedy the defect?

27. The two needles of an ordinary astatic galvanometer are not equally magnetised, and the pair is not therefore perfectly astatic. Would you

expect to obtain a greater deflection with a given current when the stronger or when the weaker needle is placed inside the coil?

28. A compass needle is removed from its case and held in a flame for a few minutes. When again placed on its pivot it does not lie in a horizontal plane. Which end will dip, and why?

• 29. You suspect that a ring of rather soft iron is strongly magnetised in a circular direction, but no lines of force can be discovered passing out of the iron. How would you prove, without breaking or cutting it, whether the ring is magnetised or not?

30. Magnetic lines of force pass more readily through iron than through brass. How would you prove this?

31. A bar magnet is fixed horizontally underneath a table, and is entirely hidden from view. How would you discover its exact position, and how would you find out which is its north-seeking pole?

32. Why are steel magnets sometimes made in a horseshoe form and sometimes straight?

33. How would you compare the magnetic strength of two small suspended magnetic needles which are of similar dimensions?

34. Why are steel magnets sometimes built up of a number of thin strips?

35. You have a pair of needles fixed in the usual manner for an astatic pair, but the upper needle is twice as strongly magnetised as the lower one. How would you fix a third unmagnetised needle of soft iron so as to render the combination perfectly astatic?

FRICTIONAL ELECTRICITY.

• 1. Given a piece of silk ribbon and some indiarubber tubing, how would you develop a charge of electricity, and how would you prove that you had succeeded in your experiment?

2. Supposing there to be no pith balls or other similar substances available, how would you prove that there are two distinct electrical states, and that bodies similarly electrified are mutually repellent, while bodies dissimilarly electrified are mutually attractive?

3. Describe an experiment to prove that the two electric states are developed simultaneously and equally.

4. What are the objects of the glass shade in a gold-leaf electroscope, and what good purpose is served by gumming strips of tinfoil on the inside of the shade? Why should these strips be earth-connected?

5. An insulated hollow metal sphere has a charge of positive electricity. What is the effect upon an electroscope placed near it? A smaller sphere has an equal negative charge, and is placed inside the other without making contact. What is now the effect upon an electroscope in the vicinity?

6. How would you demonstrate that an electrified body must electrify a previously unelectrified body before attraction can take place?

7. Distinguish between conductors and non-conductors, and divide the following substances into these two classes, placing the conductors in the order of their relative conductivities, and the non-conductors in the order of their relative insulating properties: Dry wood, green wood, brass, iron, air, pure water, brine, sulphur, coke, paraffin wax, colza oil, ebonite, sealing-wax, shellac, silver.

8. What do you understand by electrical potential? If of two equal spheres one is charged with three units of positive electricity, and the other with one unit, what will be their relative electrical condition after having been placed momentarily in contact?

9. Three units of positive electricity are communicated to an insulated sphere, and one unit of negative to a similar insulated sphere. The two spheres are placed momentarily in contact. What is the subsequent electrical condition of the spheres?

10. A highly electrified conductor is placed near an insulated sphere, but not near enough for a spark to pass. The sphere is touched by the hand, and a spark passes between the electrified conductor and the sphere. How do you account for this?

11. Two insulated spheres of equal dimensions are connected by a fine wire, and a positively electrified glass rod is held near one of the spheres. The hand having been protected by an indiarubber glove, the wire is carefully removed, and then the glass rod withdrawn. What is the electrical condition of the spheres?

12. A long fine wire is connected to a brass sphere mounted on a glass rod, and the free end of the wire is looped round an electrified ebonite rod without touching it. What will be the effect upon the wire? How will the charge on the ebonite rod be affected? What will be the electrical condition of the sphere when the wire is removed?

13. Two brass spheres, one being three times the diameter of the other, are mounted on glass rods, and four units of electricity are communicated to the smaller sphere. The spheres are then allowed to touch each other. What will be the relative potential of the two spheres (1) while they remain in contact, and (2) when they have been separated? Give reasons for your answer.

14. What is the effect of connecting to earth by means of a piece of wire (1) a positively electrified brass sphere; (2) a negatively electrified brass sphere?

15. A certain amount of work has to be done in order to give a conductor a definite negative potential, that is to say, to lower its potential to a definite value below that of the earth. What happens when this conductor is earth-connected; and what becomes of the energy expended in electrifying the conductor?

16. A positively electrified conductor is connected to earth by a long wire. What happens? What would you do in order to keep the conductor at a higher potential than that of the earth?

17. Describe, with diagrams, the construction of a 'frictional' machine.

18. Explain the action which takes place when a frictional machine is worked.

19. How would you negatively electrify a conductor by means of a frictional machine?

20. Why is it necessary, in order to obtain a continuous succession of sparks from the prime conductor of an electrical machine, that the rubber should be earth-connected?

21. Why is it that the charge which can be communicated by the prime conductor of an electrical machine to an insulated sphere is limited?

22. When the rubber of an electrical machine is earth-connected, a person standing on the floor can obtain an unlimited number of sparks from the prime conductor, but when he stands on a sheet of ebonite, the flow of sparks soon ceases. How do you account for this?

23. What are the causes which limit the length of a spark obtainable from a frictional machine?

24. In an ordinary frictional machine rubbers are placed at the top as well as at the bottom of the plate. Why is this? Why is it advisable when a charge is to be collected from the prime conductor to place one hand on the knob connected with the upper rubber?

25. What advantage, if any, is obtained by mounting the plate of a frictional machine upon a glass instead of a metal spindle?

26. What would happen if the comb of a frictional machine were made of a slab or disc of ebonite furnished with a number of pins, these pins being simply fastened into the ebonite without any metallic connection between them?

27. Why are the prime conductor of a frictional machine and its connections rounded and kept free from sharp bends or corners?

28. When an electrified conductor approaches but does not touch an electroscope, the divergence of the leaves is only temporary, the leaves falling together again when the conductor is removed; but if the conductor touches the electroscope, the divergence of the leaves continues after the withdrawal of the conductor. Explain this.

29. What is a Leyden jar? Why should the glass be thin? What is electrically the best way of connecting the inner coating with the knob?

30. If you desired to obtain the greatest possible discharge from three Leyden jars, how would you connect them together, and with the machine? Give a diagram.

31. What objections, if any, are there to coupling a large and a small Leyden jar together and charging them from the machine simultaneously?

32. Why are not the coatings of a Leyden jar extended to the top of the glass vessel, and why is it preferable to construct the jar without the usual wooden cap or cover?

33. A charge of electricity is communicated to an insulated pear-shaped conductor. Where is the charge densest? What is the effect of bringing an earth-connected unelectrified sphere near the larger end of the conductor? What would ensue if a needle were attached to the sphere on the side nearest the charged conductor; and why?

34. How would you discharge an electrified ebonite rod speedily without damping or wetting it?

35. Why are glass rods which are employed for insulating purposes sometimes coated with shellac varnish?

36. Why is it more necessary to warm glass than ebonite before attempting to electrify it by rubbing?

37. You have a charged Leyden jar, and you wish to determine whether the outer coating is positively or negatively electrified. How would you do this?

38. How would you arrange matters so that the leaves of an electroscope diverge (instead of collapsing) when the knob is touched by hand?

39. A positively charged metal ball is supported on a glass rod. How would you by means of this ball obtain (*a*) a negative charge, (*b*) a positive charge, on a proof plane?

40. An electroscope possesses a charge which causes the leaves to remain divergent, but you do not know whether the charge is positive or negative. How would you decide this point without taking any charge from the electroscope?

41. I have a strongly electrified brass ball suspended by a silk thread.

I want to completely discharge the ball and yet retain the whole of the charge on another conductor. How can this be accomplished?

42. You wish to impart to a Leyden jar as great a charge as possible by means of an electrophorus. State exactly how you would proceed. How would you know when you had reached the limit?

43. Two insulated metal spheres of exactly equal dimensions are charged positively. How would you prove whether their charges are equal or not?

44. An electrified conductor is brought to a distance of four inches from the cap of an electroscope. Would you expect the leaves to diverge to a greater extent when the electroscope stands on a table or when it stands on a slab of ebonite?

45. An electrified metal ball is made to touch the cap of an electroscope. The divergence of the leaves is less when the cap is connected to the inner coating of an uncharged Leyden jar than when it is not so connected. Why is this?

46. The cap of an electroscope is connected to earth by means of a wire. How would you produce a divergence of the leaves?

47. Why is it necessary for the lower end of a lightning conductor to be in good electrical connection with the earth?

48. An electrical machine and a Leyden jar are placed on an insulating stand, the rubber of the machine being connected to the outer coating of the jar and the prime conductor to the inner coating. The machine is worked and the jar becomes charged. The jar is then removed from the insulating stand and placed upon the table. Describe the changes which take place in the value of the potential of the inner and outer coatings respectively.

49. If you wished to charge a Leyden jar in such a way that the potential of its outer coating should be (1) below that of the earth, (2) equal to that of the earth, how would you proceed?

VOLTAIC ELECTRICITY.

1. Why should the armature of an electromagnet be equal in sectional area to the sectional area of the core?

2. Why is the Grove cell not used in cases where it is required to maintain a current for several days?

3. Give sketches showing the distinction between right- and left-handed helices.

4. What is a galvanometer, and why are the layers of wire alternately right- and left-handed helices?

5. Why is a galvanometer with a horizontal needle more sensitive than one with a vertical needle?

6. A coil of wire six inches long is wound over an iron core an inch in diameter. The outside diameter of the coil is three inches, and the wire is one-sixteenth of an inch thick. How many convolutions will the coil contain?

7. The resistance of iron wire being six times that of copper of the same dimensions, what is the resistance of ten miles of iron wire one-eighth of an inch thick when the resistance of a copper wire twenty miles long and a quarter of an inch thick is 20 ohms?

8. The resistance of a mile of copper wire a quarter of an inch thick is

1 ohm. What is the resistance of seventy miles of copper wire one-eighth of an inch thick?

9. A current is sent through a wire stretched between the floor and ceiling of a room. How, with the aid of a magnetised needle, would you ascertain whether the current is travelling upwards or downwards?

10. How would you prove that a piece of wet string is a poorer conductor than a piece of copper wire of the same dimensions?

11. What are the names of the practical units of resistance, electromotive force, and current strength?

12. Explain the terms 'resistance,' 'electromotive force,' and 'current strength.'

13. Why is the Leclanché cell more suitable than any other type of cell for intermittent work?

14. Why does the Daniell cell polarise when the sulphate of copper has been exhausted?

15. Why is it usual to wind the coils of electromagnets over the legs only, instead of uniformly over the whole of the core?

16. Why is steel never employed for the cores of electromagnets?

17. Why, in practice, are electromagnets usually made of the U or horseshoe shape?

18. You cannot obtain so strong a current by means of an electrical machine as you can with a single Grove cell, although the electromotive force of the former is hundreds of times greater than that of the latter. Why is this?

19. What happens when a small quantity of sulphate of copper gets into the zinc division of a Daniell cell?

20. What is the precise effect of the sulphate of copper solution in a Daniell cell becoming weak?

21. Why is iron wire unsuitable for galvanometer coils?

22. Resistance coils are sometimes enclosed in a metal case in order that they may be immersed in a bath of oil or water. What is the object of this arrangement?

23. Why is the wire which is employed for resistance coils or for the coils of a galvanometer covered throughout with an insulating material?

24. Why is copper wire unsuitable for resistance coils?

25. A plate of zinc four inches square and a plate of copper two inches square are connected to a galvanometer, and completely immersed in a sulphuric acid solution, and a certain deflection of the needle obtained. Would you expect a greater, equal, or less deflection when the zinc plate measures two inches square, and the copper plate four inches square, the distance between the plates being the same on both occasions?

26. If you wish to make a short piece of platinum wire as hot as possible by means of a current, would you select Grove cells or Daniell cells for your battery? Say why.

27. Two pieces of copper wire, each six inches in length, are joined side by side (in parallel) across the poles of a battery of five Grove cells. One wire is twice as thick as the other, and the thicker wire is found to become hotter than the thinner wire. Why is this?

28. How would you prove that the resistance of a solution of salt and water is less than that of water?

29. What means would you adopt to prove that the resistance of a solution of sulphate of copper becomes less as its temperature is increased?

30. How would you show that the resistance of a copper wire increases with an increase in its temperature?

31. When a copper wire and an iron wire of the same length and diameter are connected separately for the same length of time across the poles of a battery of five Grove cells, the copper wire becomes hotter than the iron wire; but when they are joined in series across the poles of the same battery, the iron wire becomes the hotter. Why is this?

32. Why does a Daniell cell remain in better condition if allowed to continually send a feeble current than if allowed to stand idle for a considerable time, with its poles disconnected?

33. If two platinum plates are dipped in a solution of sulphuric acid, and a current from a battery is sent through the liquid from one plate to the other for a few minutes, and the battery then disconnected, a current can be obtained from the plates for a short time. What causes this current?

34. If the original current (see preceding question) be obtained from a single Daniell cell, the secondary current cannot be obtained on disconnecting the cell. How do you account for this?

35. Two copper plates are immersed in a solution of sulphuric acid, and a similar pair in a solution of sulphate of copper. Although the distance between the plates is adjusted so that the resistance between the one pair is exactly equal to that between the other pair, a single Grove cell can, when joined up to them in turn, send a much stronger current between the plates in the copper sulphate solution than between those in the sulphuric acid solution. What is the reason for the difference?

36. A battery consisting of five Grove cells and five Daniell cells is joined up to a galvanometer, and the needle is deflected to a less extent than when the five Daniell cells are entirely removed. What is the reason?

37. Describe an experiment which will prove that a greater electromotive force can be obtained with zinc and carbon plates in a solution of sulphuric acid than with zinc and copper plates in the same solution.

38. Given a compass needle, a helix of wire, a battery, and two rods of iron of similar dimensions, how would you determine which of the two samples of iron is the more suitable for the core of an electromagnet?

39. A Smee cell loses slightly in weight when it is allowed to send a current for a considerable time, but a Daniell cell remains constant in weight. How do you account for this?

40. Given a helix of wire connected to a galvanometer at some distance from it, but with no battery joined in the circuit, how would you produce a deflection of the galvanometer needle by means of the helix and a bar magnet?

41. How would you reverse the direction of the deflection obtained in the preceding experiment?

42. A piece of iron tubing is slipped over an electromagnet of the same length. Compare the magnetic condition of the tube with that of the core when a current is sent through the coil.

43. A helix is held vertically, and the north-seeking pole of a bar magnet approaches it from above. The result is that a current is developed in the helix. Will the direction of this current be right- or left-handed as viewed from above the helix?

44. A battery is employed to send a current by means of copper electrodes through solutions of sulphate of copper, nitrate of silver, sulphate of zinc, and sulphate of sodium, contained in separate vessels. What chemical changes take place in each case?

45. Two platinum plates, each measuring two inches square, are immersed in a cell containing a sulphate of zinc solution, and joined to a voltaic battery. In another similar cell are immersed two platinum plates, each measuring four inches square. What will be the relative amounts of chemical action in the two solutions (1) when the cells are joined in series; (2) when they are joined in parallel to the same battery, the resistance of the battery being very low?

46. Distinguish between the Grove and Bunsen cells, and mention their relative advantages and disadvantages.

47. A copper wire one-tenth of an inch in diameter and ten yards long is joined in series with an iron wire one-fifth of an inch in diameter and ten yards long. Supposing these wires to be connected to a battery, in which of them will the greater amount of heat be liberated?

48. Before an electric arc can be established between two carbons, it is necessary that the carbons be placed in contact. Why is this?

49. Two similar electromagnets are joined in parallel and connected to a battery of two Leclanché cells. They are then joined in series to a battery of four Leclanché cells. The resistance of the cells is very low indeed when compared with the resistance of the electromagnet coils. In which case, if in either, would you expect the consumption of zinc to be the greater, and why?

50. Describe, with diagrams, the construction of an ordinary trembler electric bell.

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